INSTRUCTION MANUAL

POLAR COORDINATE
PATTERN RECORDER

SERIES APR 30

SERIAL NO.

MP MASTER
MA29835

SCIENTIFIC-ATLANTA, INC.

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POLAR COORDINATE PATTERN RECORDER

SERIES APR 30

SERIAL NO. _____

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I. GENERAL DESCRIPTION

1.1 Introduction

Scientific-Atlanta, Inc., Series APR 30 Polar Coordinate Pattern Recorders are designed to permit rapid and accurate recording of either of three functions of the amplitude of a received signal plotted versus an angular function of the reception or transmission device. These recorders are ideally suited for making permanent radiation pattern recordings of reception and transmission devices sensitive to media such as radio frequencies, heat, light, sound, etc.

When fed from a square-law detector or transducer, the recording may be presented as a function of the received power, the received voltage, or the logarithm of the received power or voltage. When fed from a linear detector or transducer, the recording may be presented as a function of the received voltage or as the logarithm of the received power or voltage. To accomplish the preceding presentations, the recorders may be furnished with one or a choice of two or more of the following pen functions: linear pen motion versus recorder input voltage; square-root pen motion versus recorder input voltage; logarithmic pen motion versus recorder input voltage.

The recorder will respond to an 80 db dynamic range of input signal providing an 80 db logarithmic scale when fed from a linear detector and a 40 db logarithmic scale when fed from a square-law detector.

To permit operation from a detector receiving an audio-modulated carrier, the recorder is furnished with a narrow-band crystal-bolometer amplifier. When using this amplifier, the recorder and the detector comprise a sensitive video detection receiving system. The detector may be coupled directly to an antenna under test or to the output of a receiving system for improvement of the over-all sensitivity.

To permit operation from a dc input signal, the crystal-bolometer amplifier is replaced by a dc-chopper preamplifier. This permits direct recording from the output of a transducer or a detector receiving an unmodulated signal.

1.2 Specifications

1.2.1 Chart System:

Chart Speed (Maximum)	10 rpm for 1:1 synchro system 4 rpm for 36:1 synchro system
Chart Position Error	
Static	0.25 degrees for 1:1 synchro system 0.05 degrees for 36:1 synchro system
Dynamic	1.5 degrees at 5 rpm for 1:1 synchro system 0.5 degrees at 1 rpm for 36:1 synchro system
Chart Motion	forward-reverse

1.2.2 Pen System:

Pen Writing Speed	40 inches-per-second
Pen Lift	manual or foot-switch
Pen Responses Available	
Model APR 31	linear
Model APR 32	logarithmic
Model APR 33	linear-logarithmic
Model APR 34	linear-square root
Model APR 35	linear-logarithmic-square root
Pen Response Accuracy	
Linear	± 0.5% of full scale
Square-root	± 0.5% of full scale, first 20 db ± 1.0% of full scale, next 20 db
Logarithmic	± 0.25 db
Pen Motor Control (On-Off)	manual or remote
Noise Compression (Noise Improvement)	10 db referred to recorder input 5 db referred to square-law input
Function Potentiometers	plug-in

1.2.3 Crystal-Bolometer Amplifier (Models CBA 21, CBA 21R, CBA 22):

Input Noise (Referred to 600 Ohm Source Impedance)	0.025 microvolt
Center Frequency (Standard)	1000 cps

Range of Center Frequencies Available	between 500 cps and 2500 cps
Bandwidth (3 db)	center frequency ±2.0%
Over-all Gain	100 db
Full Scale Sensitivity:	
Linear	1 microvolt
Square-root	10 microvolts
Logarithmic	100 microvolts
Attenuation*:	
Fixed	three 10 db steps
Variable	10 db

1.2.4 DC-Chopper Preamplifier (Model DCA 21):

Over-all Gain (dc to rms ac)	20 db
Full Scale Sensitivity:	
Linear	10 millivolts
Square-root	100 millivolts
Logarithmic	1 volt
Attenuation**:	
Fixed	three 20 db steps
Variable	20 db
Attenuator Accuracy (Fixed Steps)	±1% of full scale
Chopper Frequency	400 cps

1.2.5 Pen Function Amplifiers:

Model PFA 21	linear
Model PFA 22	logarithmic
Model PFA 23	linear-logarithmic
Model PFA 24	linear-square root
Model PFA 25	linear-logarithmic-square root
Signal Level Meter Calibration (All Models)	0-20 db 0-40 db

*Attenuation referred to square-law recorder input.

**Attenuation referred to linear recorder input.

1.2.6 Plug-in Potentiometers:

P-1	linear
P-2	linear-square root
P-3	logarithmic (40 db)
P-3-20	logarithmic (20 db)
P-4*	logarithmic (60 db)

1.2.7 General:

Power Requirements

Voltage	115
Frequency	50-60 cps
Watts	300
Weight	145 pounds

1.3 Principles of Operation

The Series APR 30 Polar Pattern Recorder consists of two high-speed servo systems each employing tachometer feedback. One servo positions a recording chart in response to the angular position of a remote synchro transmitter; the other positions a recording pen in response to a function of the signal applied to the input of the recorder preamplifier.

1.3.1 Chart System:

Figure 1 is a block diagram of the Series APR 30 Polar Coordinate Pattern Recorder. Chart position data is normally obtained from either of two synchro transmitters: one geared 1 to 1 with respect to the antenna turntable; the other geared 36 to 1 with respect to the antenna turntable.

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*Used in combination with Series 402 Wide Range Receiving System.

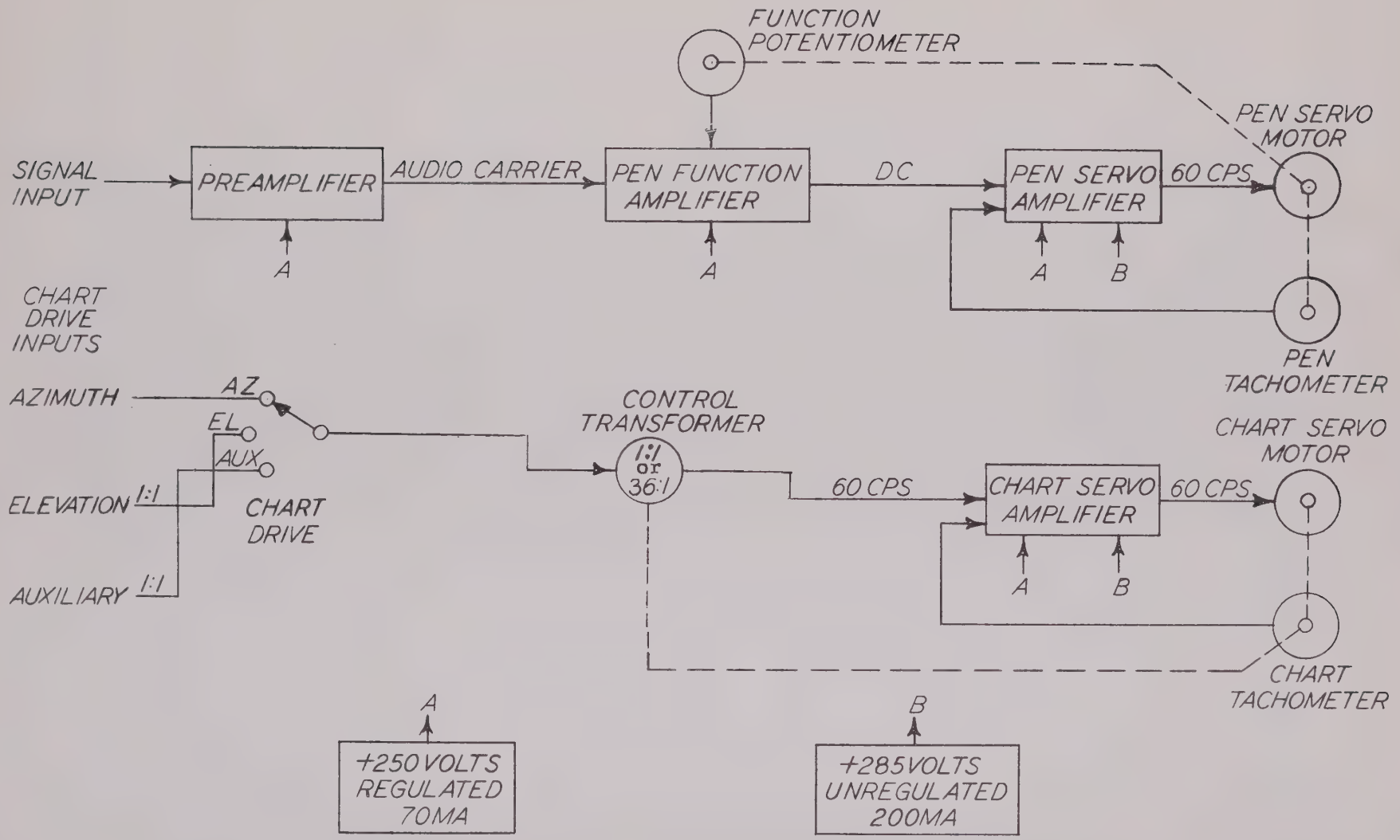

Figure 1. Block Diagram of Series APR 30 Polar Coordinate Pattern Recorder

The pattern recorder turntable is synchronized with a synchro transformer. This synchro transformer is normally furnished geared either 1 to 1 or 36 to 1 with respect to the turntable.

A CHART MOTION switch (not shown by Figure 1) provides selection of the direction of chart rotation during normal operation.

A CHART DRIVE switch provides selection of any one of three pairs of synchro inputs to drive the chart. These inputs are labeled AZIMUTH, ELEVATION, and AUXILIARY. This permits rapid switching of the chart system between axes of an antenna positioner or between antenna positioners.

The chart servo amplifier is a 60 cps amplifier which accepts an error signal from the appropriate control transformer and drives the chart servo motor. The chart servo motor includes an integral tachometer providing damping control.

All polar recorders having model numbers ending with S136 are furnished with both a 1:1 and 36:1 synchro transformer. Included with these polar recorders are a 1:1 synchro phase error meter and a synchro selector switch to provide a means of maintaining phase synchronization between the recorder turntable and the antenna positioner.

1.3.2 Pen System:

The control signal for the pen system is applied to the input of a preamplifier which furnishes an audio carrier to the pen function amplifier. The preamplifier may be either a crystal-bolometer amplifier (See Crystal-Bolometer Amplifier Instruction Manual) or a dc-chopper preamplifier (See DC-Chopper Preamplifier Instruction Manual). The frequency of the audio carrier fed to the pen function amplifier depends on the type of preamplifier and its center frequency. This frequency will be in the frequency range between 400 cps and 2500 cps.

The pen function amplifier (See Pen Function Amplifier Instruction Manual) provides additional amplification of the audio carrier and furnishes a dc error voltage to the pen servo amplifier. In addition, the pen function amplifier includes the circuits which together with the proper plug-in potentiometer determine the pen function. Five plug-in models of the pen function amplifier are available permitting a pattern recorder to have a single pen function which is either linear or logarithmic, a choice of two pen functions (linear-square root or linear-logarithmic) or a choice of three pen functions (linear-logarithmic-square root).

The dc output of the pen function amplifier is fed to the pen servo amplifier. This amplifier converts the dc input into a 60-cycle signal and delivers a 60-cycle output to the pen servo motor. The pen servo motor has an integral tachometer which is fed into the pen servo amplifier to provide pen damping. The recording pen and the appropriate function potentiometer or potentiometers are driven by the pen servo motor.

1.3.3 Pen Functions:

Figure 2A shows a block diagram of the basic circuit arrangement which provides the linear pen function. It is desired to provide a recorder pen displacement (P) which is directly proportional to the amplitude of the input signal E_s. The quantities shown by Figure 2A are as follow:

E_s	input signal
A	amplifier gain
E_d	amplifier output
$-E_b$	reference voltage
$-E_r$	potentiometer arm potential
e	error signal
P	recording pen displacement

The equations which describe the circuit operation are as follows:

(1) $$E_d = AE_s$$

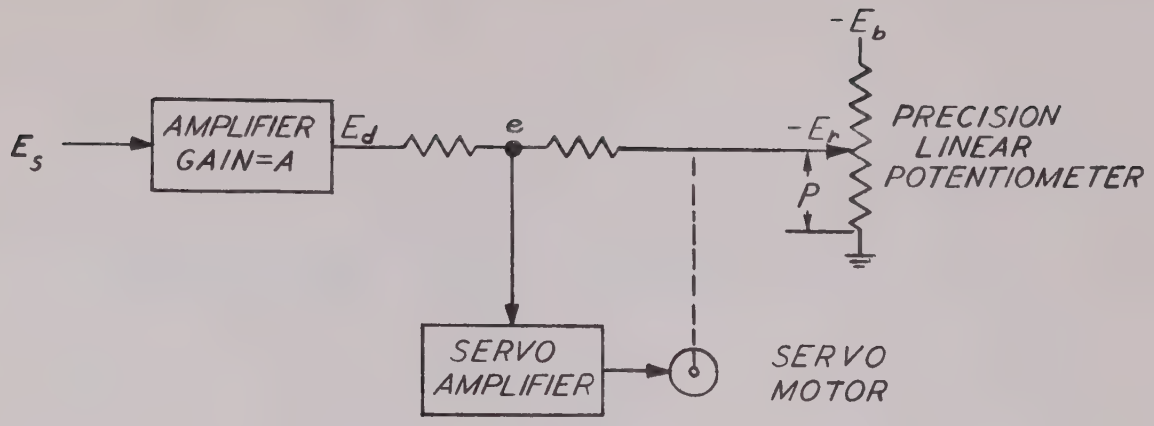

Figure 2A. Simplified Linear Pen Function Circuit.

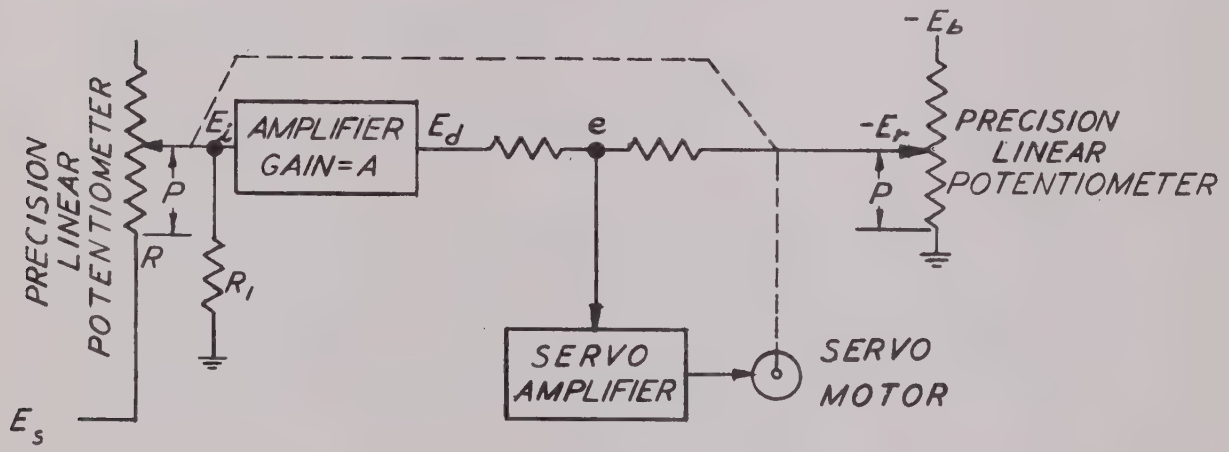

Figure 2B Simplified Square-Root Pen Function Circuit.

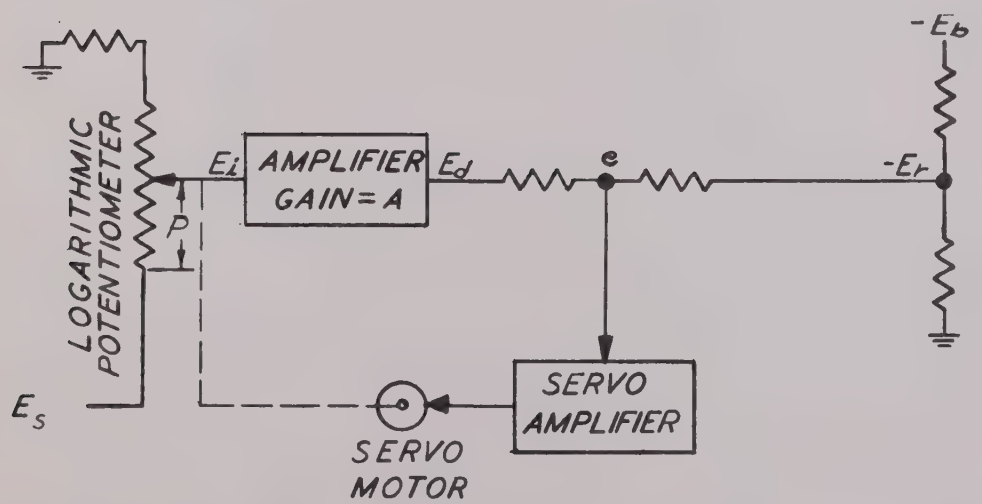

Figure 2C. Simplified Logarithmic Pen Function Circuit.

(2) $$E_r = PE_b$$

With the high gain servo loop continually adjusting $-E_r$ to balance E_d maintaining the error signal (e) at minimum or zero, then:

(3) $$E_r = E_d$$

Substituting PE_b for E_r and AE_s for E_d gives:

(4) $$PE_b = AE_s$$

Since A and E_b are constants:

(5) $$\underline{P = KE_s}$$

Figure 2B shows a block diagram of the basic circuit arrangement which provides the square-root pen function. In this case, it is desired to provide a recorder pen displacement (P) which is directly proportional to the square-root of the amplitude of the input signal (E_s). The quantities shown by Figure 2B are as follow:

E_s	input signal
E_i	amplifier input
R	linear potentiometer resistance
R_l	load resistance
A	amplifier gain
E_d	amplifier output
$-E_b$	reference voltage
$-E_r$	potentiometer arm potential
e	error signal
P	recording pen displacement

The equations which describe the circuit operation are as follow:

(1) $$E_i = \frac{E_s R_1}{R_1 + PR}$$

If $R_1 << PR$, which is accomplished over the desired range of P by making R large and R_1 small then:

(2) $$E_i = \frac{E_s R_1}{PR}$$

(3) $$E_d = AE_i$$

(4) $$E_d = \frac{AE_s R_1}{PR}$$

(5) $$E_r = PE_b$$

With the high gain servo loop continually adjusting $-E_r$ to cancel E_d maintaining the error signal (e) at minimum or zero then:

(6) $$E_r = E_d$$

Since the two linear potentiometers are mechanically ganged the pen displacement is common to both. Substituting PE_b for E_r and $\frac{AE_s R_1}{PR}$ for E_d gives.

(7) $$PE_b = \frac{AE_s R_1}{PR}$$

(8) $$P^2 = \frac{AE_sR_1}{RE_b}$$

Since $\frac{AR_1}{RE_b}$ is constant:

(9) $$\underline{P = K\sqrt{E_s}}$$

Figure 2C shows a block diagram of the basic circuit arrangement which provides the logarithmic pen function. In this case, it is desired to provide a recorder pen displacement (P) which is directly proportional to the logarithm of the amplitude of the input signal (E_s). The quantities shown by Figure 2C are as follow:

E_s	input signal
E_i	amplifier input
A	amplifier gain
E_d	amplifier output
$-E_r$	reference voltage
e	error signal
P	recording pen displacement

The equations which describe the circuit operation are as follow:

(1) $$E_i = \frac{E_s}{\log^{-1} P}$$

(2) $$E_d = \frac{AE_s}{\log^{-1} P}$$

With the high gain servo loop continually adjusting E_d to cancel $-E_r$ maintaining the error signal (e) at minimum or zero, then:

(3) $$E_r = E_d$$

Substituting $\frac{AE_s}{\log^{-1} P}$ for E_d gives:

(4) $$E_r = \frac{AE_s}{\log^{-1} P}$$

(5) $$P = \log \frac{A}{E_r} + \log E_s$$

Since $\frac{A}{E_r}$ is constant

(6) $$\underline{P = \log E_s + K}$$

1.3.4 Noise Compression Circuit.

The noise compression circuit is located in the 60 cps pen servo amplifier and provides a reduction of the recording pen noise response equivalent to 10 db of signal level referred to the recorder input. (Figure 3 illustrates the noise improvement to be expected when the noise compression circuit is used during recording.)

A NOISE COMPRESSION switch permits the noise compression circuit to be either inserted or removed from the pen servo amplifier. When in the OFF position of the NOISE COMPRESSION switch, the noise compression circuit is removed from the pen servo amplifier. When in the ON position of the NOISE COMPRESSION switch, the noise compression circuit is inserted in the pen servo amplifier as shown by Figure 4.

The noise compression circuit performs three basic functions

a. Circuit A consisting of R6, CR5, and CR6 limits the level of the error signal fed to the 60 cps output amplifier to a

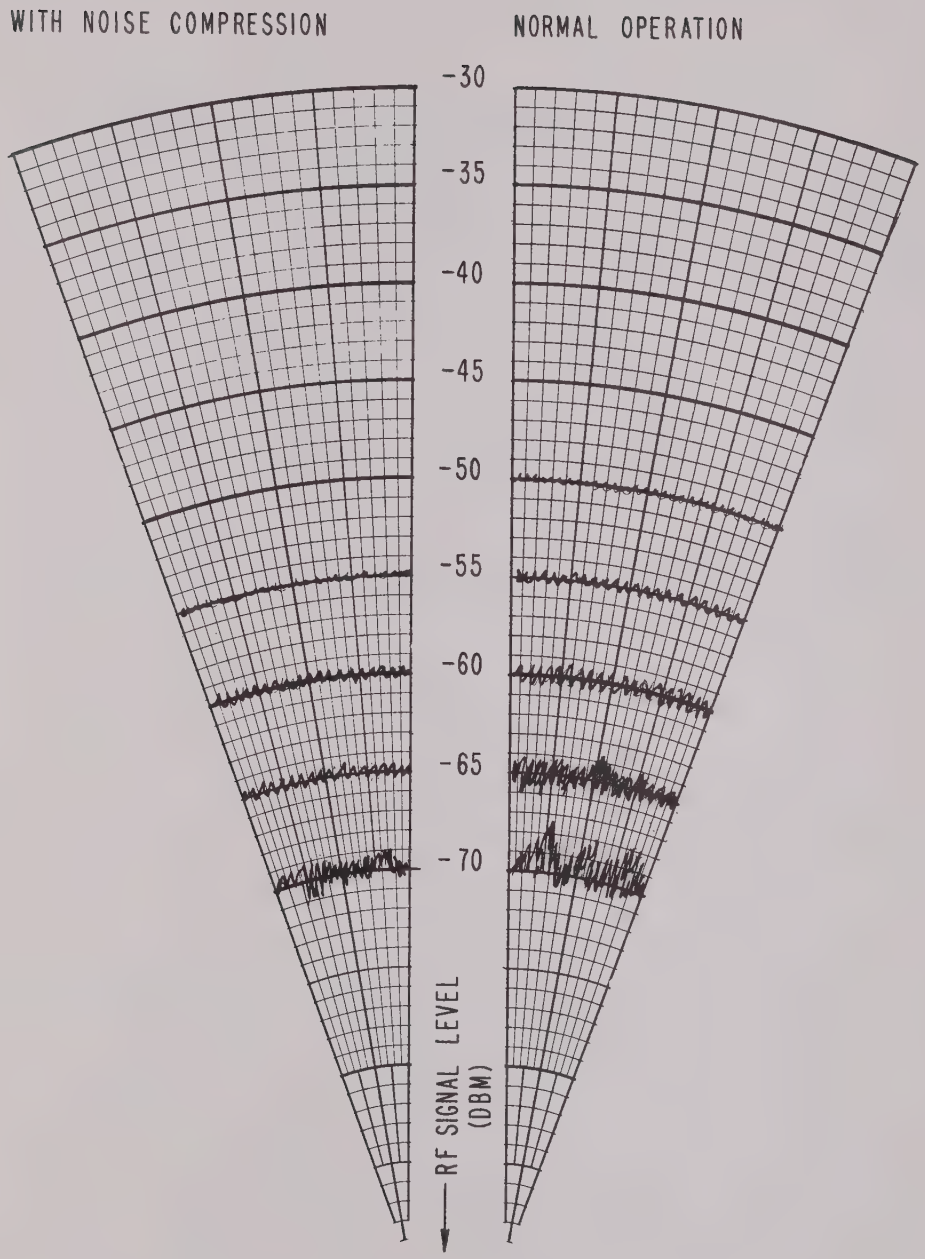

Figure 3. Typical Recorder Noise versus R-F Signal Level With and Without Noise Compression (Operation at "X" Band using 1N23C Crystal)

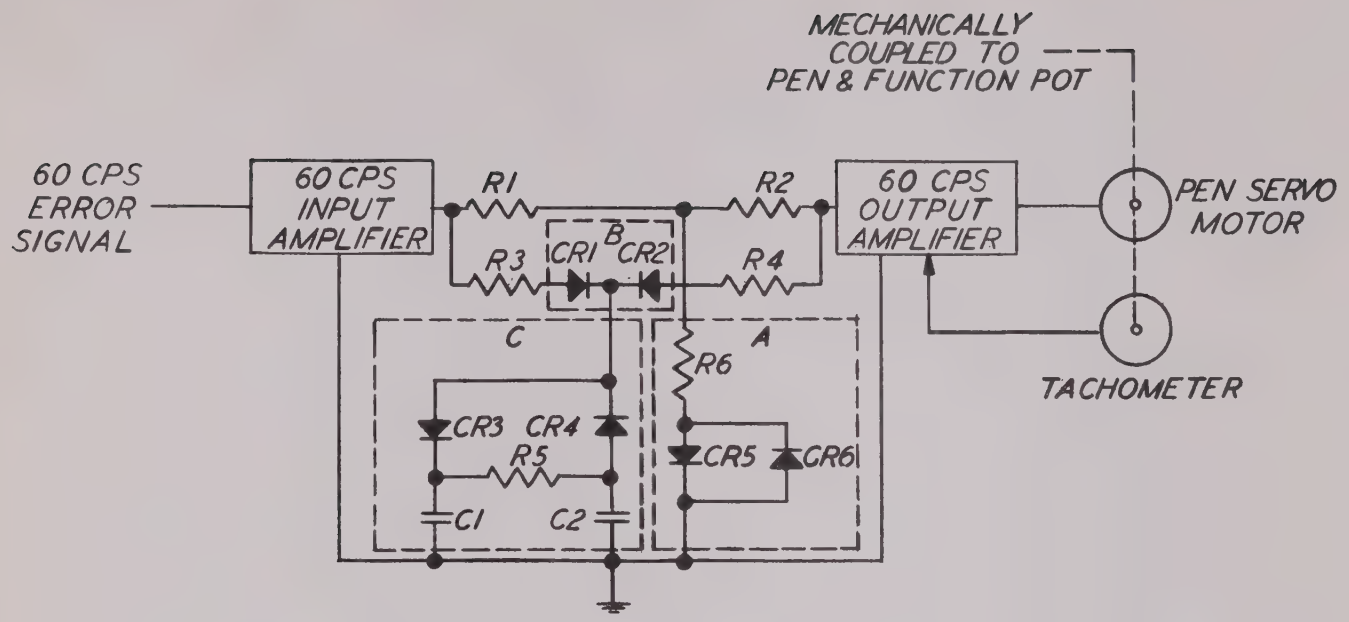

Figure 4. Simplified Noise Compression Circuit.

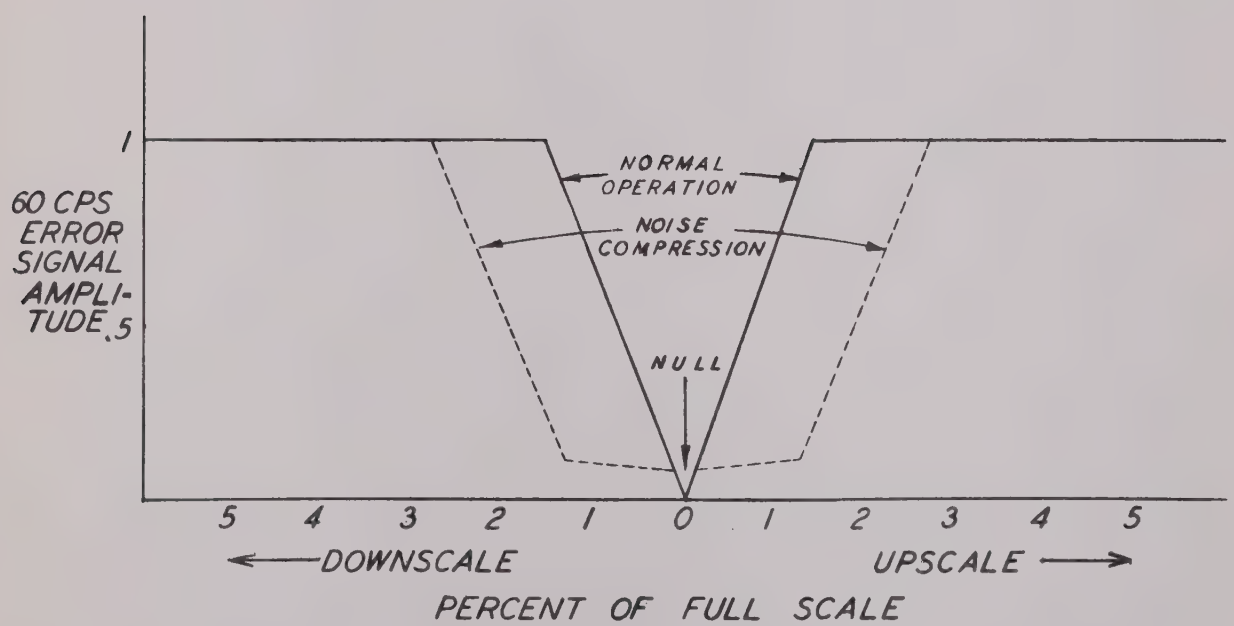

Figure 5. Error Signal versus Pen Displacement from Null for Normal and Noise Compression Operation.

value which provides a maximum pen slewing speed of approximately 2 to 3 inches-per-second. Since CR5 and CR6 are silicon diodes requiring approximately 0.5 volts of applied signal before conduction, the recording pen response is unaffected when the recording pen is within a region of approximately ±0.02 inch of the null.

b. Circuit B consisting of CR 1 and CR 2 restores full error voltage when displacement of the recording pen from the null exceeds a predetermined value. Full error voltage is coupled to the 60 cps output amplifier upon conduction of CR 1 and CR 2. The voltage required to render CR 1 and CR 2 conductive corresponds to the applied error voltage present when the recording pen is displaced from null by 0.125 inch. This corresponds to 1.25 per cent of the full linear scale or approximately ±0.5 db of the logarithmic scale.

c. Circuit C consisting of CR3, CR4, R5, C1, and C2 discriminates between random noise and a constant error signal. The diodes are germanium diodes and conduct upon application of potential. Upon conduction of CR3 and CR4, Circuit B is loaded and the response of the servo amplifier is limited by Circuit A. Circuit C is disabled by a bias voltage built up on C1 and C2 when a constant error voltage is applied. The time constant provided by R5, C1, and C2 is sufficiently short to allow Circuit C to disable Circuit B only when random error signals of short duration are present.

Figure 5 shows the over-all response of the pen servo amplifier for normal operation and when using the noise compression circuit. The solid curve represents the relative amplitude of the error signal plotted versus pen displacement from a null during normal operation. In this case, a maximum pen slewing speed of 40 inches-per-second is attained. The dashed curve shows the deviation from the normal amplifier response when using the noise compression circuit. At a region within ±0.2 per cent of the null, the amplifier response is unaffected. In the region between

±0.2 per cent of the null and ±1.25 per cent of the null, the amplifier response is limited. Outside the region of ±1.25 per cent of the null, the full error signal is applied for non-random signals.

The over-all effect of the noise compression circuit is to provide a pen response similar to that obtained with a preamplifier having a 4 cps bandwidth without incurring the modulation frequency stability requirement and slow response limitation of the narrow-band amplifier. The noise compression circuit permits pattern recording at normal recording speeds with a maximum dynamic system error of ±1.25 per cent of the full linear scale or ±0.5 db of the logarithmic scale. The static or slow speed (pen speeds less than 2 inches-per-second) error is not increased over that specified for normal operation. (See Figure 6.) At maximum pen speeds between 2 inches-per-second and 20 inches-per-second the error due to the noise compression circuit is less than the maximum (±1.25 per cent of full scale) and proportional to the pen speed. As can be seen by the lower curve of Figure 6, the apparent effect of the amplitude lag is to displace the over-all pattern slightly on the axis of the chart.

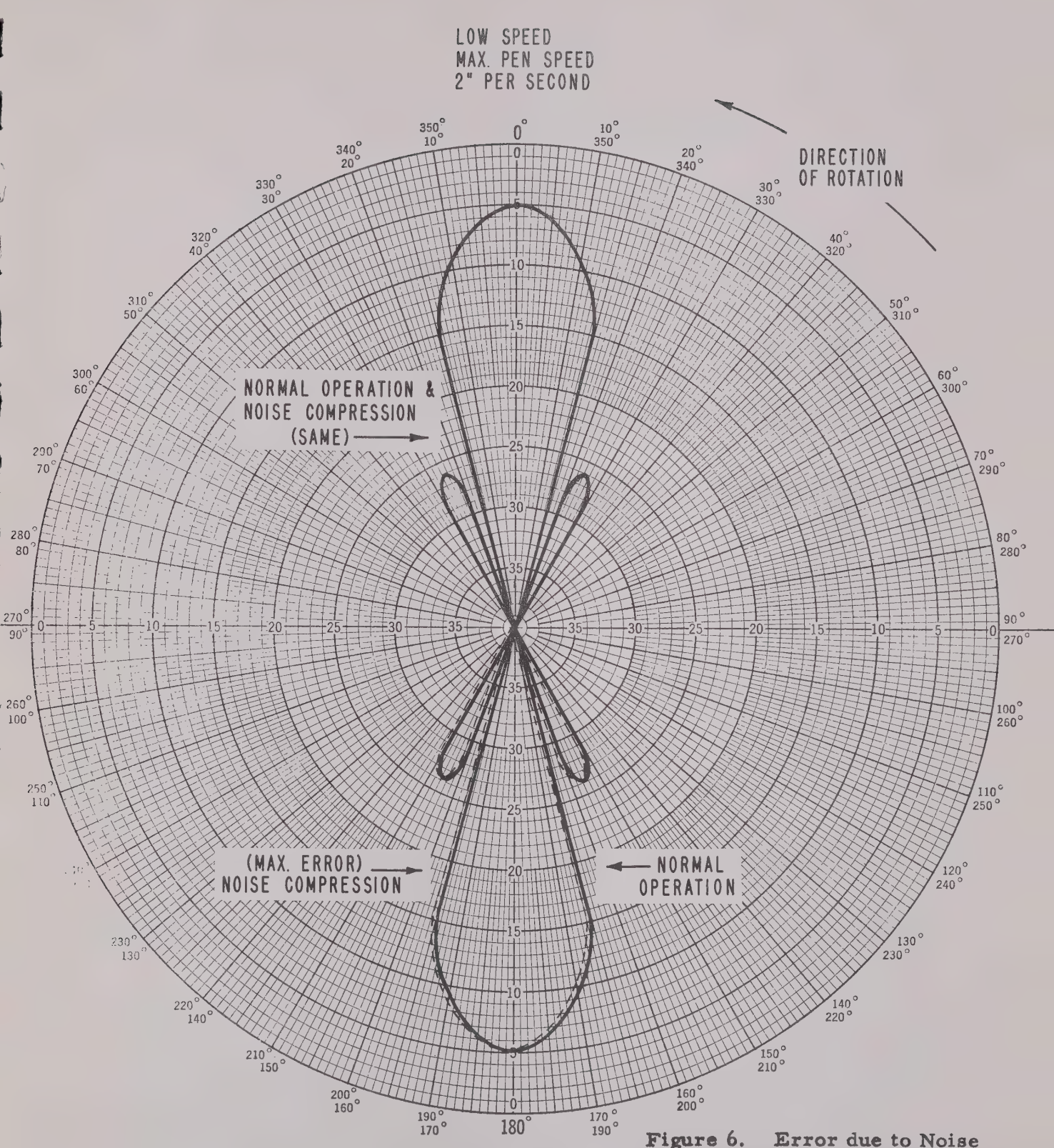

Figure 6. Error due to Noise Compression Circuit at High and Low Pen Speeds

Polar Chart No. 127D
SCIENTIFIC-ATLANTA, INC.
ATLANTA, GEORGIA

II. OPERATING INSTRUCTIONS

2.1 Installation and Operation

The Series APR 30 Polar Pattern Recorder operates from a 115 v, 50-60 cps line and requires approximately 300 watts of input power. A visual inspection of all cables and tubes to assure proper placement should be made after uncrating. A preamplifier and a pen function amplifier will be plugged into the lower and upper compartments of the amplifier and power supply chassis on portable models. These units may be separately rack-mounted and remoted from the recorder when the recorder is console mounted. In this case, the plug-in compartments of the recorder will have blank covers.

A Scientific-Atlanta Series PX 1 Synchro Transmitter Unit or its equivalent should be used to furnish synchro data for the chart system (See Figure 7). This unit should be mechanically coupled to the required axis of the antenna positioner. The pattern recorder has three input connectors and a CHART DRIVE switch to permit front panel selection of any one of three synchro transmitter units, each coupled to a separate positioner axis. Connection from each recorder chart synchro input to a Series PX 1 Synchro Transmitter Unit requires up to an 8-conductor cable fitted with Amphenol AN 3106A-20-7S and AN 3106A-20-7P cable connectors. Cable conductor size should be sufficient to carry 0.5 amperes.

The output from a crystal or bolometer detector is normally connected to the INPUT of the crystal-bolometer amplifier. If a bolometer is used, the BOLOMETER CURRENT control should be turned fully counter-clockwise before connecting the bolometer. The CRYSTAL-CURRENT-BOLOMETER switch should be placed in the CURRENT position while adjusting the bolometer current. After adjustment, this switch should be thrown to the BOLOMETER position.

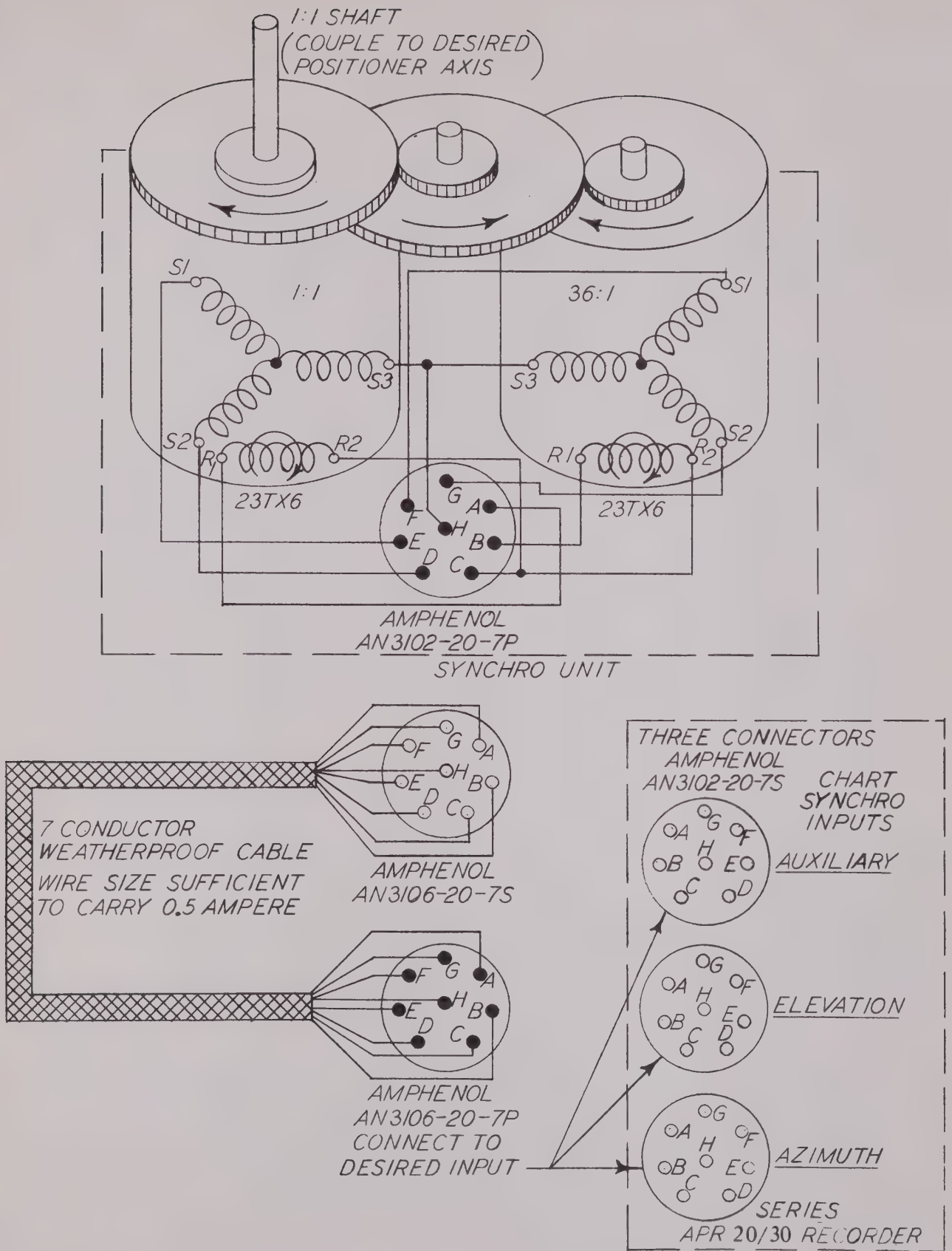

Figure 7. Chart System Connections to Series PX 1 Synchro Unit.

For operation from a crystal detector, the CRYSTAL-CURRENT-BOLOMETER switch must be in the CRYSTAL position.

In recorders furnished with a dc-chopper preamplifier in place of the crystal-bolometer amplifier, a dc input signal is fed to the INPUT connector. For complete details of preamplifier operation, see the instruction manual furnished with the particular plug-in unit.

The recorder pen functions available are determined by the particular pen function amplifier and plug-in potentiometers furnished. The proper plug-in potentiometer and pen function amplifier combination must be employed to obtain a particular pen function. For specific information concerning the proper plug-in potentiometer for a particular pen function, see the pen function amplifier instruction manual provided.

2.2 Chart System Controls

The polar pattern recorder has three front-panel controls which determine the operation of the chart system. The name and function of each control follows:

a. SYNCHRO SELECTOR (36:1 - 1:1)
Purpose: This switch permits selection of either a 1:1 or a 36:1 drive ratio between the antenna positioner and the recorder turntable allowing phase synchronization between the antenna positioners and the recorder turntable to be maintained when operating from the more accurate 36:1 control system. This switch is furnished only with polar recorders having model numbers ending with S136.

b. CHART DRIVE (AZIMUTH-ELEVATION-AUXILIARY)
Purpose: This selector switch permits the rapid selection of any one of three predetermined synchro inputs for turntable synchronization.

c. CHART MOTION (FORWARD-REVERSE)

Purpose: This switch permits the direction of rotation of the turntable to be reversed with respect to the direction of rotation of the synchro transmitters and antenna turntable.

2.3 Pen System Controls

The performance of the pen system is determined by controls located on the panel of the polar recorder head, controls located on the front panel of the plug-in preamplifier and the pen function amplifier, and remote controls which may be connected beneath the polar recorder head. For a description of the controls located on the crystal-bolomter amplifier, the dc-chopper preamplifier, or the pen function amplifier, refer to the separate instruction manual furnished with a particular unit. A description of the controls located on the polar recording head panel and the remote controls which may be connected beneath the polar recorder head follows:

a. PEN MODE (LOAD-LIFT-WRITE)

Purpose: This switch performs two functions: (1) When in the LOAD position, the pen is automatically lifted and positioned to the full scale pen stop position to facilitate chart loading; (2) When in the LIFT position, the pen is lifted from the chart writing surface and the recorder may be operated without writing. The pen should be lifted when positioning or replacing the chart and when it is necessary to refill or replace the pen.

b. PEN MOTOR (ON-OFF)

Purpose: This switch permits the pen drive motor to be turned off when recording is not desired. The pen motor should be turned off when cable connections affecting the pen position are being made and when recording is not desired. A minimum of function potentiometer wear can be achieved by not allowing the pen to idly follow large random noise signals for long periods of time.

c. PEN LIFT - Remote Control

Purpose: A foot-operated switch may be attached to the rear of the pattern recorder head to provide foot operation of the pen lift circuit when the PEN MODE switch is in the LIFT position. Use of the foot switch provides a convenient means of beginning and terminating the inking of a pattern.

d. PEN MOTOR (ON-OFF) - Remote Control

Purpose: A connection is provided at the rear of the recorder head to permit remote ON-OFF control of the pen motor. For remote operation, the PEN MOTOR switch must be in the OFF position. This feature permits the pen motor to be remotely controlled when the recorder is operated in conjunction with an analog computer.

2.4 Loading Chart Paper

To install a piece of chart paper on the recorder turntable, the PEN MODE and PEN MOTOR switches should be switched to the LOAD and ON positions respectively. This will cause the pen to automatically lift and position itself at the full-scale pen stop. The chart paper can then be placed on the turntable and its center precisely positioned over the lighted turntable center hole. Holding the chart paper in place with one hand, place the small permanent magnets on the periphery of the chart. These magnets hold the chart paper to the turntable and prevent slippage. The turntable is linked to the turntable drive mechanism through a slip clutch and may be rotated in either direction to facilitate alignment of the chart axis with that of the antenna being tested.

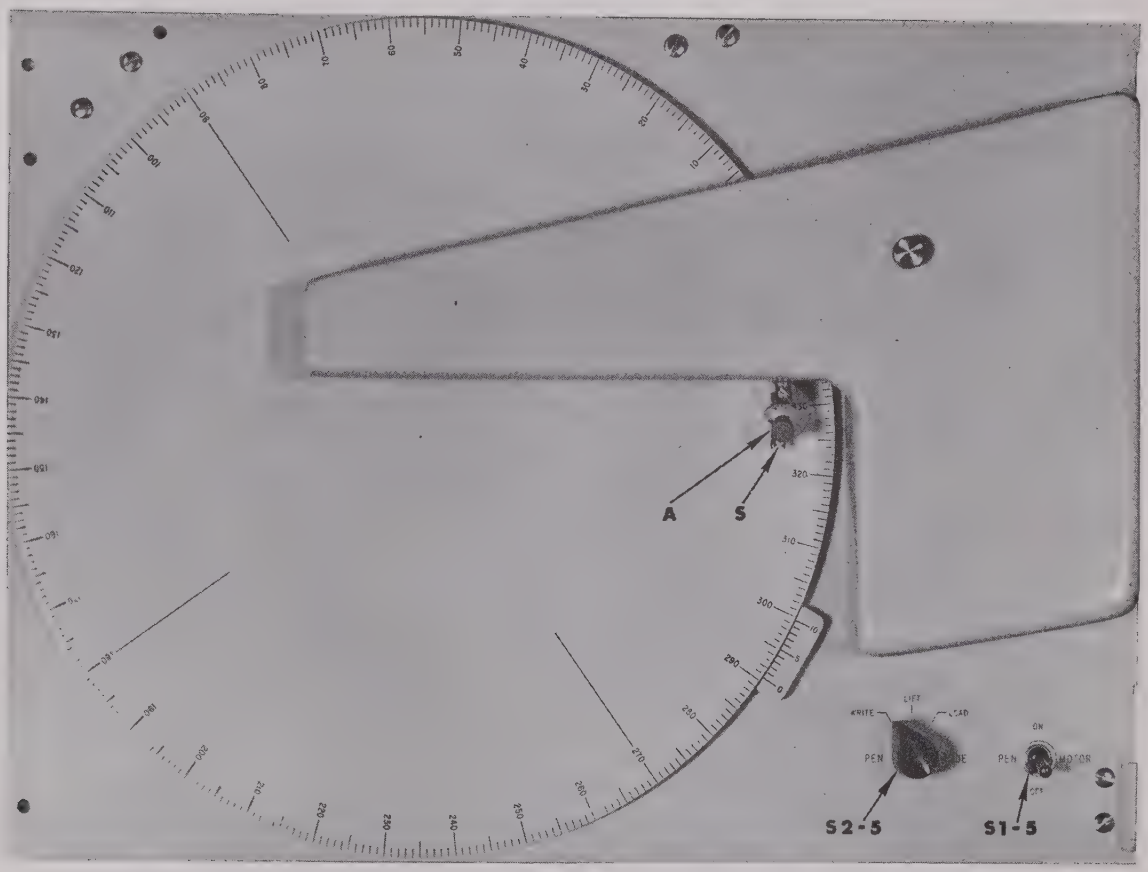

Figure 8. Top View of Polar Pattern Recorder Head With Cover

2.5 Removal and Installation of Plug-in Potentiometer

The underside of the recorder head is exposed by lifting the handle at the left rear corner until the recording surface is oriented vertically. The support brace should snap into place and hold the recorder head in this position.

To allow removal of the plug-in potentiometer, which will now be located in the bottom rear corner of the recorder head, disconnect the cable connector from the bottom of the potentiometer housing. Grasp the potentiometer and rotate approximately 45 degrees clockwise, pull to the left, and remove the potentiometer.

To install a plug-in potentiometer, hold the potentiometer in the left hand with the cable connector down. From the front of the recorder, observe the two holes in the side of the potentiometer casting and then orient the potentiometer with one hole facing up and one hole facing to the rear of the recorder. Orient the potentiometer arm with the hole in the potentiometer casting facing up. Turn the slotted arm (V, Figure 11) fixed to the shaft on the pen drive panel to face up. While maintaining the described orientation, insert the potentiometer into position and guide the potentiometer pin into the slot provided. This can be observed through the hole facing up. Press the potentiometer against the pen drive panel and rotate counterclockwise until the potentiometer is locked firmly in position. Attach the connector to the bottom of the potentiometer. The plug-in potentiometer is now ready for operation.

The recorder head is returned to its operating position by grasping the handle at the upper rear corner, pushing the lock button on the support brace, and gently lowering the recorder head.

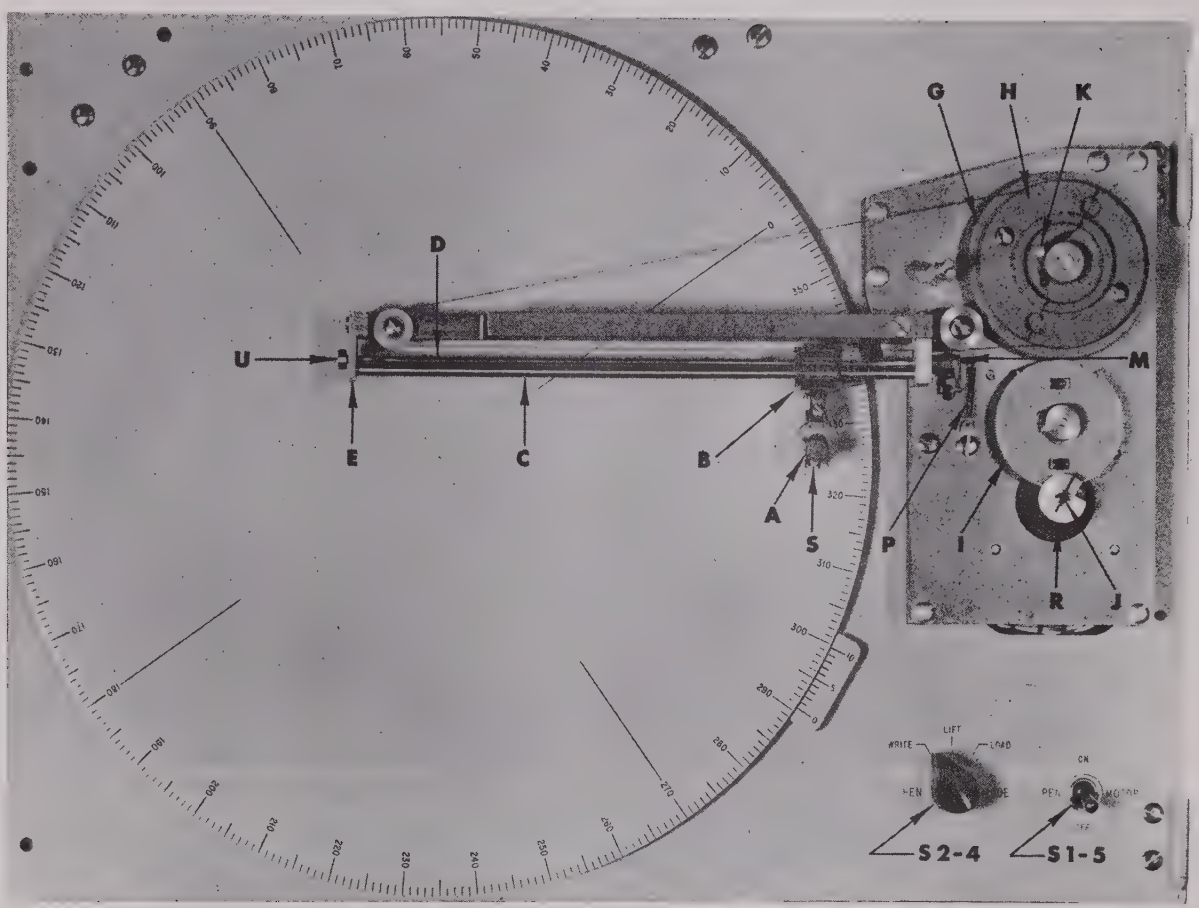

Figure 9. Top View of Polar Pattern Recorder Head Without Cover

2.6 Operational Notes

a. Connection of the ground wire provided in the power cord to a zero potential ground is recommended unless another ground path is provided as may be the case when the recorder is housed in a console.

b. Avoid dual grounds causing ground loop currents wherever possible.

c. Always place the CRYSTAL-CURRENT-BOLOMETER switch in the CRYSTAL position when operating from a crystal detector and in the BOLOMETER position when operating from a bolometer detector. Be sure the BOLOMETER CURRENT control is fully counterclockwise before inserting a new bolometer.

d. The step attenuator located on the crystal-bolometer amplifier front panel may be used to obtain accurate antenna patterns exceeding a 40 db dynamic range. This is particularly useful in examining side lobes and nulls of a pattern.

e. Use the PEN MODE switch to prevent inking when recording is not required.

f. The average life of the balance potentiometer is 2-million cycles. When not actually recording, the PEN MOTOR should be turned OFF, especially if the noise level is high.

g. Use the signal level meter as a level indicator when recording is not desired. This will greatly increase potentiometer life.

h. In normal operation, pens will need cleaning every two or three days. This may be done by passing the fine wire supplied with the pen through the pen point.

i. Placing of a polar chart on the turntable is facilitated by placing the PEN MODE switch in the LOAD position.

j. The center frequency of the crystal-bolometer amplifier is determined by a plug-in filter. Filters are available at any frequency between 500 cps and 2500 cps.

k. Two pattern recorders may be operated from a single bolometer. This procedure is described in the Crystal-Bolometer Amplifier Instruction Manual.

l. The PEN-LIFT may be operated by a foot switch to facilitate the control of pattern inking.

m. Use the noise compression circuit to observe side lobes obscured by noise. Do not use the noise compression circuit when noise level reduction is not required.

III. DETAILED DESCRIPTION

3.1 Construction

The Series APR 30 Polar Pattern Recorders are constructed to provide maximum circuit accessibility to facilitate maintenance and adjustment while providing adequate electrostatic and magnetic shielding between sensitive circuits and sources of electric and magnetic fields. Particular attention has been given to interconnecting ground circuits to prevent inter-unit coupling caused by ground loops (See Figure 15).

The amplifiers and power supply assembly of the recorder is designed for mounting on rack slides, and many of the recorder circuits are accessible from the sides when this chassis is in the extended position. Variable components which require only occasional adjustment are provided with lock nuts and are arranged to be accessible from either front, top, or side of the chassis.

Both the sensitive preamplifier and the pen function amplifier are plug-in units housed in shielded cans when in position. The lower shield can which houses the preamplifier is constructed of high-permeability material. Both the preamplifier and the pen function amplifier are supplied with regulated dc filament voltages.

The balance potentiometers used with the pen system are housed in self-aligning plug-in cases and allow rapid replacement without the necessity of adjustment.

3.2 Preamplifiers

The plug-in preamplifier furnished with the polar recorder may be either a crystal-bolometer amplifier, a dc-chopper preamplifier, or both. The crystal-bolometer amplifier permits the recorder pen system to be directly driven from an audio voltage or from a crystal or bolometer detector receiving an audio-modulated r-f carrier. For operation from a crystal detector receiving an unmodulated r-f carrier or from a direct input, the dc-chopper preamplifier must be used. This amplifier employs a mechanical chopper to convert an input dc voltage to a 400-cps carrier.

This carrier is fed through a narrow-band amplifier to limit noise.

A complete description of the crystal-bolometer amplifier and the dc-chopper preamplifier will be found in the separate instruction manuals provided with these units.

3.3 Pen Function Amplifier

The pen function amplifier is a plug-in unit which provides the necessary amplification and switching to generate one or more recorder pen functions. Five models of this unit are available permitting a wide selection of pen function combinations. The model numbers and pen functions provided are as follows:

Model	Pen Functions
PFA 21	linear
PFA 22	logarithmic
PFA 23	linear-logarithmic
PFA 24	linear-square root
PFA 25	linear-square root-logarithmic

A complete description of the pen function amplifier will be found in the Pen Function Amplifier Instruction Manual.

3.4 Pen Servo Amplifier

A circuit diagram of the pen servo amplifier will be found at the top of Figure 16 located at the rear of this manual. This amplifier consists of stages V1-1, V2-1, and V3-1, V4-1.

A unipolar dc error voltage is furnished to the input of the pen servo amplifier through pin A of J4-1. This voltage is directly applied to the arm of the chopper (K1-1). This chopper together with T1-1 furnish a 60 cps voltage proportional to the dc input to the grid of the first half of V1-1. Both triodes of V1-1 are resistance-capacitance coupled amplifiers which are cascaded and drive either the GAIN potentiometer (R17-1) when the NOISE COMPRESSION switch (S1-1) is OFF or the input of the noise com-

pression circuit when the NOISE COMPRESSION switch is ON. When S1-1 is in the OFF position, the noise compression circuit is removed and the GAIN potentiometer is coupled to the output of the second half of V1-1 through R14-1, R15-1, and C3-1. The network consisting of R11-1, CR1-1, CR2-1, CR4-1, C4-1, C5-1, and R12-1 is actually a part of the noise compression circuit which is not removed when S1-1 is in the OFF position. This portion of the noise compression circuit, however, has only a slight resistive loading effect on the amplifier output. When S1-1 is in the ON position, the noise compression circuit performs the following functions:

a. The signal coupled to the GAIN potentiometer through R14-1 and R15-1 is limited upon conduction of CR5-1 and CR6-1. These diodes are silicon diodes and conduct only when the applied potential exceeds approximately 0.5 volts. The diodes are paralleled to provide bipolar limiting of the signal. The level of signal normally applied to CR5-1 and CR6-1 is such that conduction occurs at the level of error voltage obtained when the recording pen is displaced by approximately 0.02 inch from a null. In the region nearer the null, full amplifier gain is available providing maximum accuracy. The amplitude of the error signal when limited by conduction of CR5-1 and CR6-1 is determined by the series resistance R16-1. The value of R16-1 is adjusted to provide a maximum recorder pen slewing speed of 2 inches-per-second when the amplitude of the error signal is not permitted to exceed the limited value.

b. A network consiting of R11-1, CR1-1, CR3-1, and R13-1 allows the signal to bypass the limiting circuit upon conduction of CR1-1 and CR3-1. In the bypass state, full error voltage is furnished to the GAIN potentiometer. Diodes CR1-1 and CR3-1 are silicon voltage regulators connected back-to-back to provide bipolar conduction at applied potential levels in excess of 4.5 volts. The normal level of error voltage appearing across these diodes is such that conduction occurs at the level of error voltage present when the recording pen is displaced from a null by ± 1.25 per cent of full scale. Thus, the recorder pen response

is limited only in a selected region about the null. The effect of this amplifier characteristic is to greatly reduce the pen response to rapid signal fluctuations with amplitudes occurring within the limited region.

c. To provide additional noise discrimination, the network consisting of CR2-1, CR4-1, C4-1, C5-1, and R12-1 is employed to enable or disable the bypass circuit. CR2-1 and CR4-1 are germanium diodes which conduct upon application of potential. During conduction of these diodes, the junction between CR-1 and CR3-1 is essentially bypassed to ground and the response of the recorder is again limited by R16-1 and the associated diodes. The diodes CR2-1 and CR4-1 will not conduct if the charges on C4-1 and C5-1 are equal to the peak signal level. The time constant of the network C4-1, R12-1, C5-1, is adjusted to allow C4-1 and C5-1 to fully charge only if several successive cycles of the 60 cps error signal occur. Therefore, for random error voltages such as noise voltages, the capacitors will be unable to completely charge and the pen amplifier response is limited.

The variable arm of the GAIN potentiometer is coupled to the grid of the first half of V2-1. This stage is a summing amplifier with the 60 cps pen tachometer signal applied to its cathode. The error signal and the tachometer signal are combined in this stage and coupled to the grid of the second half of V2-1. This stage is a phase splitter which provides two out-of-phase signals for the push-pull output stage.

The push-pull output stage consisting of V3-1, V4-1, and T2-1 provides the necessary power amplification to drive the 500 ohm control winding of the pen servo motor. The primary of T2-1 is resonated at approximately 60 cps to provide both harmonic rejection and a signal phase shift. A 90-degree phase relationship must exist between the voltage applied to the pen motor reference winding and that applied to the control winding. The reference winding of the pen motor is energized from the ac line. The ac error voltage is initiated by the chopper which is also energized from the ac line. The chopper, however, has an inherent phase lag. This lag together with additional phase lags introduced by the shunt capacitor (C6-1) and by the resonant primary of

T2-1 provide a total signal phase shift of 90 degrees. The secondary of T2-1 provides a 500 ohm output impedance and delivers a maximum power of 14 watts to the control winding of the pen servo motor.

3.5 Chart Servo Amplifier

A circuit diagram of the chart servo amplifier will be found at the right center of Figure 16 which is located at the rear of this instruction manual. This amplifier consists of stages V5-1, V6-1, and V7-1, V8-1.

A 60 cps error voltage coupled from the appropriate chart synchro transformer is applied to the GAIN control R33-1. The 60-cps chart tachometer signal is applied to the TACHOMETER control (R31-1). These two voltages are summed by a resistive network (R34-1 and R32-1) and are applied to the grid of V5-1. V5-1 is a phase-splitting amplifier which drives the push-pull power amplifier consisting of V7-1, V8-1, and T3-1. The primary of T3-1 is resonated at approximately 60 cps to provide both harmonic rejection and a signal phase shift. A 90-degree phase relationship must exist between the voltage applied to the chart motor reference winding and that applied to the control winding. The voltages for both the motor reference winding and the synchro transmitter rotor winding are obtained from the power line and are in phase. It is therefore necessary to provide a 90-degree phase shift in the chart servo amplifier. This is accomplished by phase leads introduced by the coupling network (C14-1, R38-1, and C13-1) and by the resonant primary of T3-1. The secondary of T3-1 provides a 500-ohm output impedance and delivers a maximum power of 14 watts to the control winding of the chart servo motor.

3.6 Power Supplies

The circuit diagrams of the plate and filament power supplies for the pattern recorder are shown on Figure 16 which is located at the rear of this manual.

The power supply consisting of T4-1, V9-1, and the associated

filter is a 285 volt, 200 ma power supply which furnishes plate potential to the push-pull power amplifiers in both the pen servo amplifier and the chart servo amplifier.

The high voltage winding of T5-1, the rectifier (V10-1), and the associated filter provide dc potential to the 250 volt regulator. This regulator consists of the series tube (V11-1), the balanced amplifiers (V12-1 and V14-1), and the reference tube (V13-1). The regulator delivers a 250 volt, 70 ma output which is furnished to all recorder amplifiers. The 150 volt potential across the regulator tube (V13-1) is employed as a potentiometer reference voltage source in the pen function amplifier and as a bolometer bias voltage source in the crystal-bolometer amplifier.

A transistor-regulated filament supply provides a 12 v dc filament voltage for the preamplifier and the pen function amplifier. This supply employs a selenium bridge rectifier operating from the 15 volt winding of T5-1. The regulator consisting of the series transistor (Q1-1), ballast lamp (RT1-1), and Zener diode CR8-1 delivers an output current of 1 ampere. R63-1 permits adjustment of the level of output voltage furnished by this supply.

3.7 Pen Drive Mechanical System

The pen drive servo motor (MG2-5, Figure 10) drives the plug-in potentiometer and the pen cable drum (H, Figure 9) through a precision gear and pinion assembly (G, I, R, Figure 9). The rotary motion of the pen cable drum is converted to linear motion of the pen across the chart writing surface by the nylon pen drive cable. A stop located on the underside of the potentiometer gear (G, Figure 9) limits the rotation of the pen cable drum and thus limits the pen travel to a distance slightly greater than the length of the chart scale.

The pen cable drum (H, Figure 9) consists of two concentrically mounted pulleys. These two pulleys are provided to allow use of 7-1/2" or 13" diameter chart paper while maintaining full scale pen travel on either. When using 7-1/2" diameter paper, the pen cable should be looped around the smaller diameter pulley (see Figure 12). When using 13" diameter paper, the larger pulley should be employed (see Figure 13).

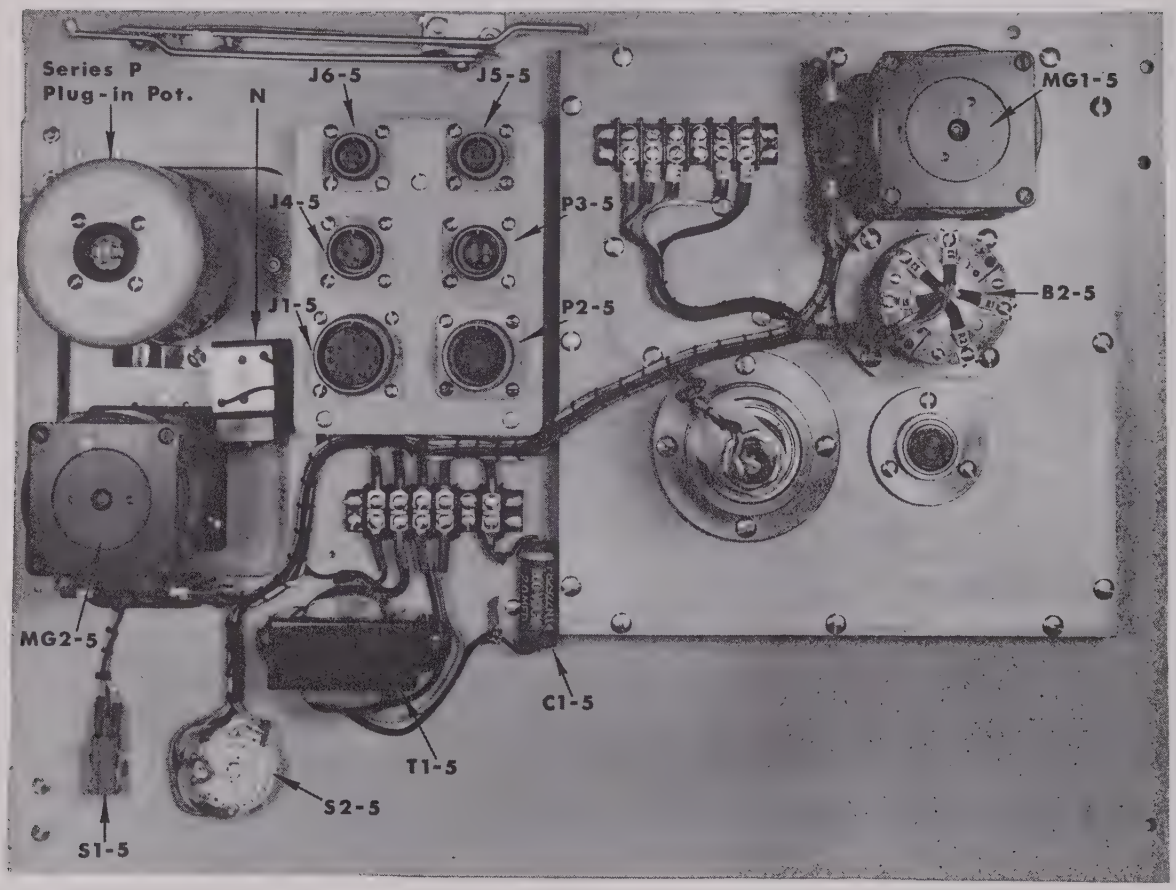

Figure 10. Bottom View of Polar Pattern Recorder Head With Plug-in Potentiometer

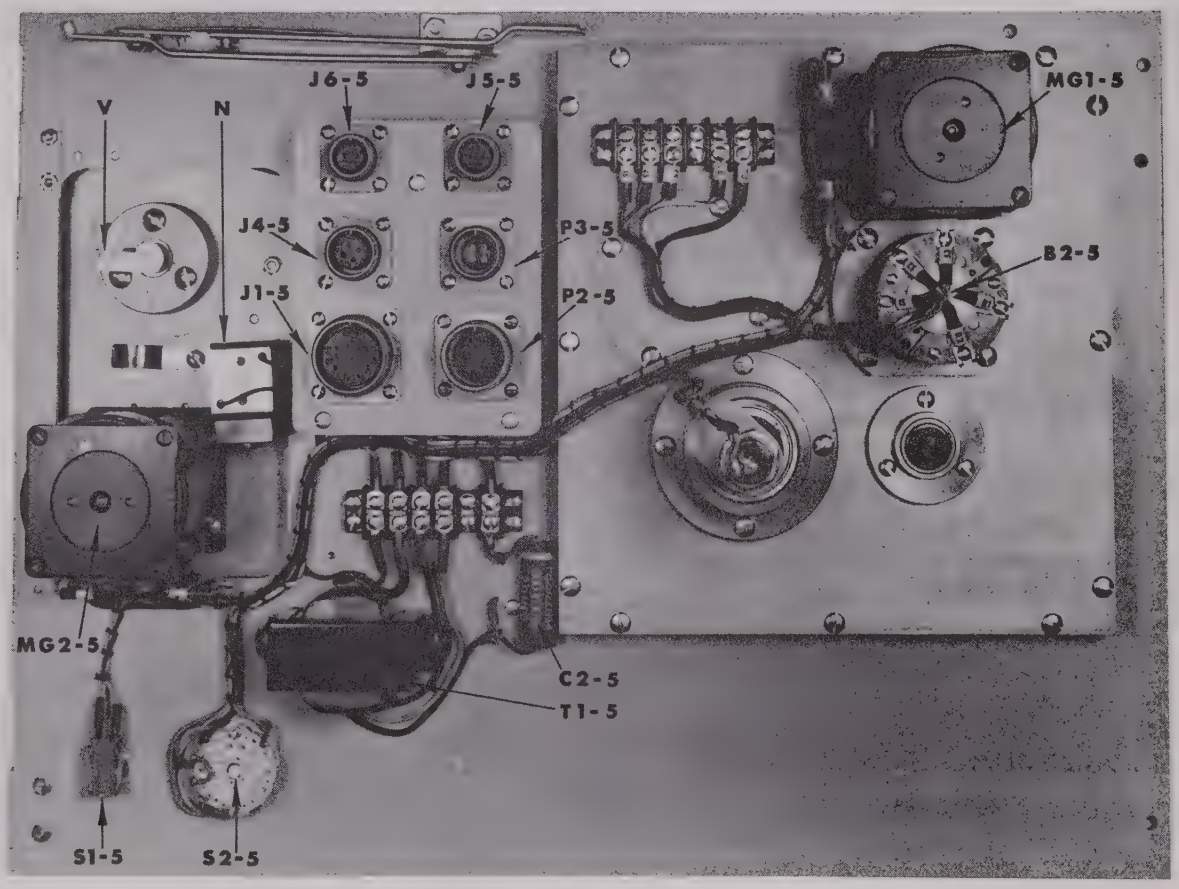

Figure 11. Bottom View of Polar Pattern Recorder Head Without Plug-in Potentiometer

The recording pen holder is fastened to the drive cable with the pen point placed 1/16 inch to the left of the turntable center hole when the pen cable drum is fully clockwise against the stop. The inking pen (A, Figure 9) is held in place in the holder (B, Figure 9) by two spring clips and a point positioning guide (S, Figure 9).

The recording pen is switched between the LIFT and WRITE positions by an eccentric bar (D, Figure 12). This lift bar is moved to a position clear of the pen holder when it is rotated by the pen lift solenoid (N, Figure 10). In this case, the weight of the pen and pen holder causes the pen to drop and contact the chart surface. When the solenoid is de-energized, the pen lift spring (P, Figure 9), rotates the pen lift bar to lift and hold the pen in the LIFT position.

3.8 Chart Drive Mechanical System

The chart drive servo motor (MG1-5, Figure 10) drives one or two synchro control transformers (depending on the model) and the turntable through a precision gear and pinion assembly. In those models having model numbers bearing the S1 suffix, synchro control transformer B1-5 (not shown, but which mounts in a position just to the left of B2-5 shown in Figure 10) is so geared to the recorder turntable that one revolution of the recorder turntable rotates the synchro through one revolution. In those models having model numbers bearing the S36 suffix, a synchro control transformer (B2-5, Figure 10) is geared to the recorder turntable so that one revolution of the recorder turntable rotates the synchro through 36 revolutions. Those models having a model number bearing the suffix S136 are equipped with both synchro control transformers. These synchro control transformers are used to obtain position information from the antenna turntable as described in Section 1.3.1. The turntable is coupled to the chart drive gear and pinion assembly through a slip clutch and may be rotated in either direction to facilitate alignment of the chart axis with that of the antenna being tested.

3.9 Chart Control Unit Circuits

Figure 18 is a diagram of the circuits associated with the Model CCU 31 and CCU 32 Chart Control Units. Both models contain the circuits for selecting the desired axis synchro inputs and chart motion.

The CHART DRIVE switch (S1-6) permits the selection of the desired axis from which synchro position information is to be obtained. The CHART MOTION switch (S2-6) selects the direction of turntable rotation by interchanging two of the stator connections on both the 1:1 and 36:1 synchro inputs for the axis selected by the CHART DRIVE switch.

The Model CCU 32 has the additional circuit of Note 2 in Figure 18. Used with all models equipped for accepting both 36:1 and 1:1 synchro input signals, this unit has a PHASE ERROR meter for detecting when the 36:1 synchro is not in the true null position. When the SYNCHRO SELECTOR switch (S3-6) is in the 36:1 position, the PHASE ERROR meter monitors the output of the synchro geared 1:1. If the meter indicates other than zero, the chart system is operating on a false null. Switching the SYNCHRO SELECTOR switch to the 1:1 position places the chart system under control of the 1:1 synchro and will slew the turntable to the predetermined null. When the SYNCHRO SELECTOR switch is returned to the 36:1 position, synchro control reverts back to the 36:1 synchro and the PHASE ERROR meter should indicate zero showing the chart system again in phase with the predetermined null. If the PHASE ERROR meter does not indicate zero, the synchros in the recorder and the synchros in the synchro transmitter package are not properly synchronized. Synchronization is accomplished by placing the SYNCHRO SELECTOR switch in the 36:1 position, loosing the fastening clamps on the 1:1 synchro, and manually rotating the housing of the 1:1 synchro until the PHASE ERROR meter indicates zero. When the recorder is operated from more than one synchro transmitter package, the synchros in the different transmitter packages must also be synchronized together.

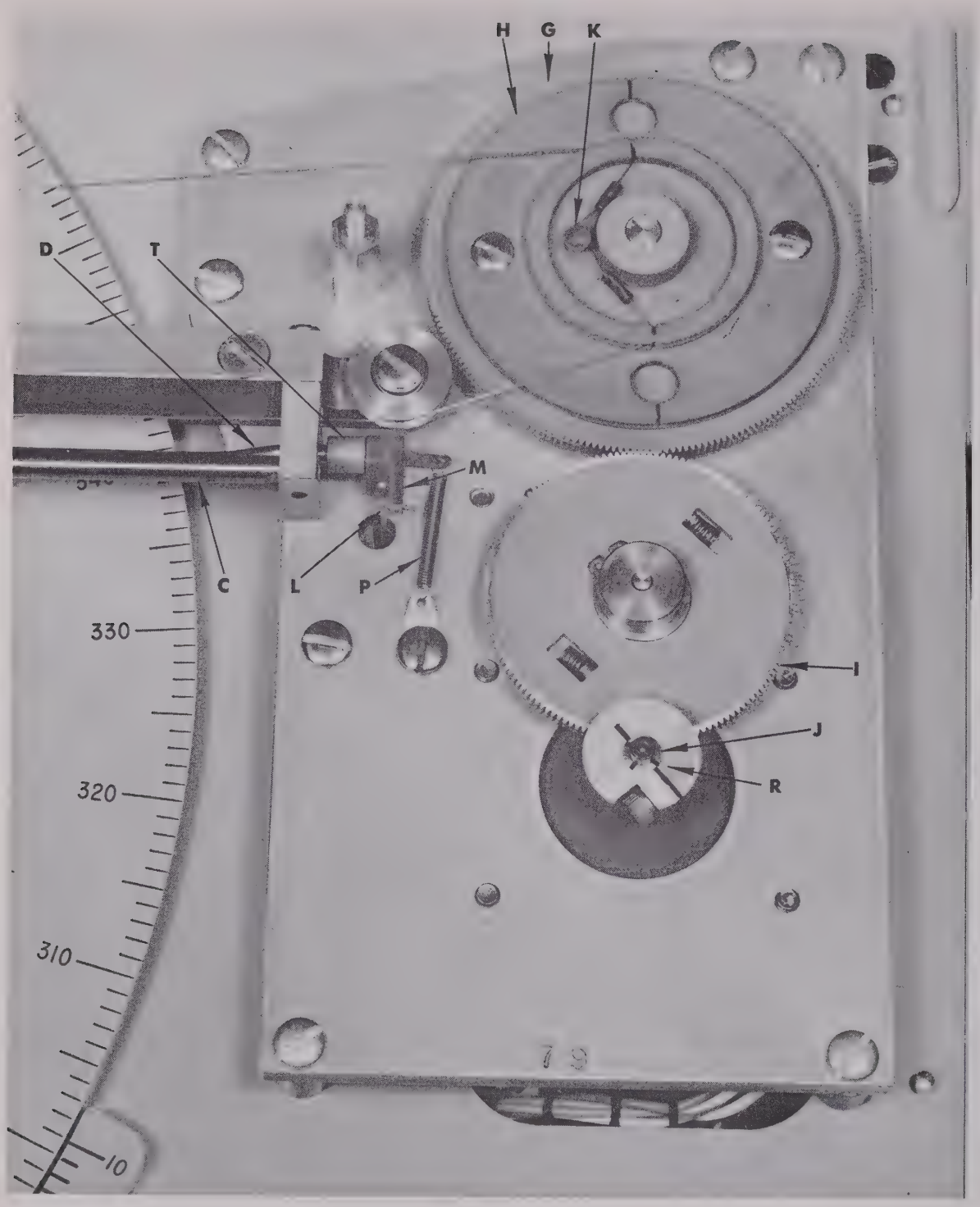

Figure 12. Close-up View of Pen Drive Mechanism with Cable Installed for Recording on 7-1/2" Diameter Paper

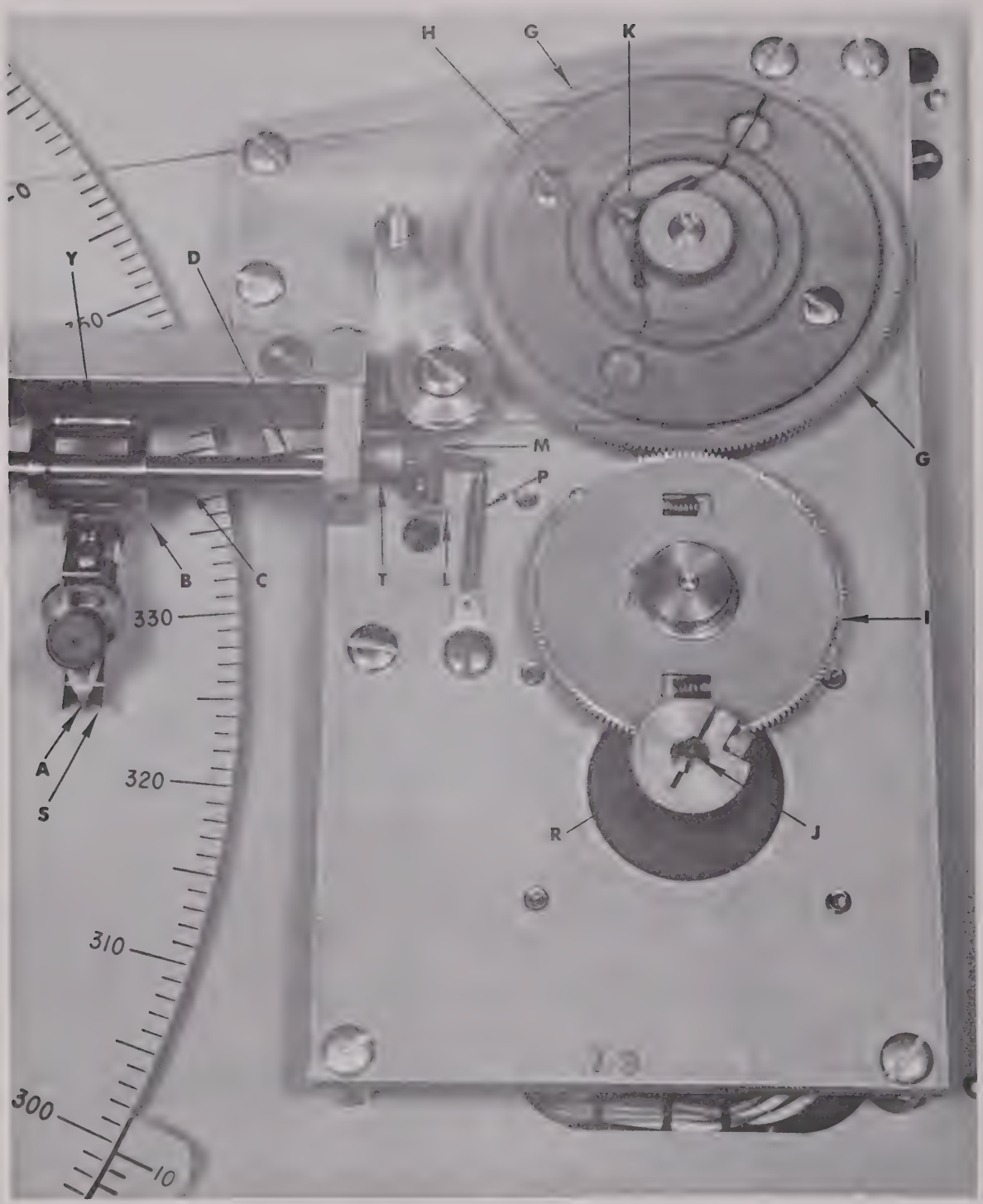

Figure 13. Close-up View of Pen Drive Mechanism with Cable Installed for Recording on 13" Diameter Paper

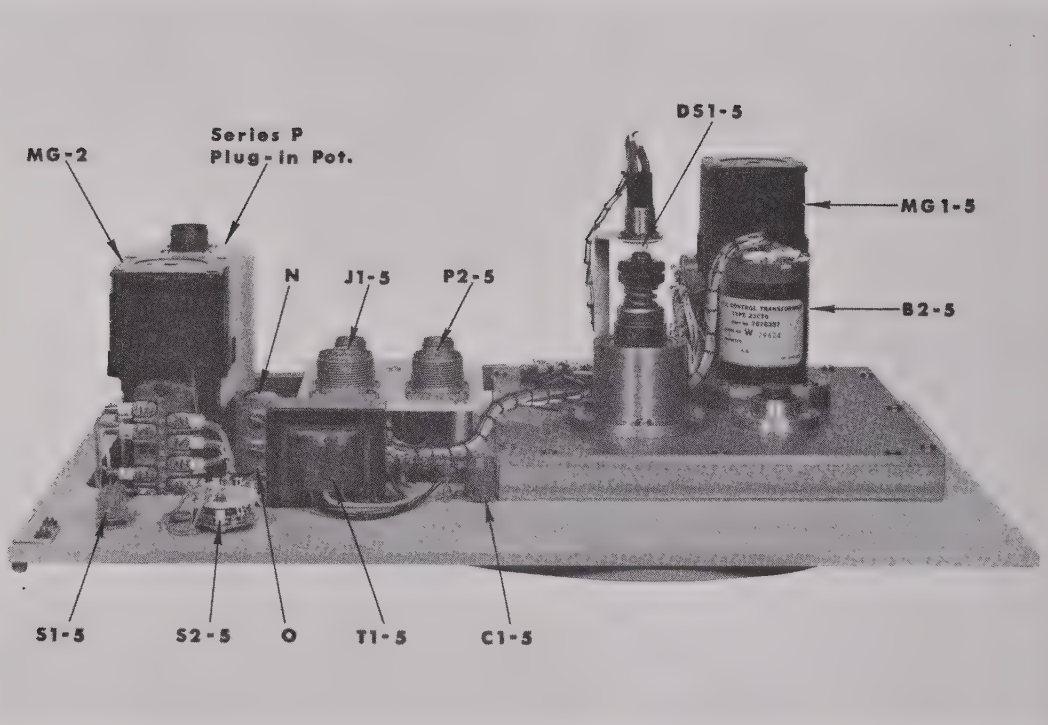

Figure 14. Front Underside View of Polar Pattern Recorder Head

IV. ADJUSTMENTS

4.1 Pen Drive System

4.1.1. Pen Drive Cable:

The pen drive cable is type 10-X nylon cord. The length of the installed cable is approximately 33 inches. Both ends of the cable are terminated in slots located in the drive drum, the ends being secured by loops around the pulley cable pin (K, Figure 9).

To enable installation of a new pen drive cable, remove the cover on the pen drive assembly, remove the old cable, and rotate the cable drive drum (H, Figure 9) fully clockwise. The new cable should have a small loop at each end and measure from end to end 32 inches.

The cable is installed for recording on 13" diameter chart paper by referring to Figure 13. One end of the cable is passed through a hole (W, Figure 13) at the right end of the pen slide bar, over the adjacent pulley, and through both slots in the 4 o'clock position of the fiber cable drive drum (H, Figure 13). The loop at this end of the drive cable is placed over the pulley cable pin (K, Figure 13). The loose end of the cable is passed through the two slots in the rear of the pen holder and over the pulley at the left end of the pen slide bar. This end is then passed clockwise around the large diameter pulley of the cable drive drum nearly one full revolution and through both slots in the drum in the 10 o'clock position. Pulling the cable taut, the looped end is placed over the pulley cable pin. CAUTION: IF ANY SLACK EXISTS, THE PEN DRIVE CABLE SHOULD BE SHORTENED BEFORE PROCEEDING FURTHER.

The pen holder is then positioned so that the pen point is 1/16 inch to the left of the center hole. The cable clamp (Y, Figure 13) is then slipped on the cable between the two slots of the pen holder and its holding screw tightened with a No. 2 Allen wrench. The cable is now installed for recording on 13" diameter chart paper.

When installing the cable for recording on 7-1/2" diameter paper, the above procedure should be followed with two exceptions: (1) The cable should be threaded only through the slots in the small diameter pulley on the cable drive drum; and (2) It will be necessary to loop the cable one extra revolution around the small diameter pulley of the cable drive drum in order to take up slack. The cable is shown installed for recording on 7-1/2" diameter chart paper in Figure 12.

4.1.2 Pen LIFT-WRITE Adjustment:

The pen LIFT-WRITE operation is accomplished by the motion of the eccentric pen lift bar (E, Figure 9) located behind and below the pen slide bar (C, Figure 9). The pen lift solenoid (N, Figure 10) is energized when the PEN MODE switch is in the WRITE position causing the eccentric lift rod to clear the rear of the pen holder assembly by approximately 1/32 inch when the pen is contacting the chart surface.

If adjustment of the pen lift rod is required, loosen the screw in the pen lift arm (M, Figure 9) and adjust the pen lift bar for a 1/32 inch clearance with respect to the pen holder with the pen lift solenoid energized. Retighten the screw.

4.2 Power Supplies

Two of the three power supplies in the pattern recorder are regulated and have voltage adjustment potentiometers which determine the levels of voltage output. Both of these adjustments are locked and require only occasional resetting.

To adjust the output level of the 12 volt dc filament supply, measure the voltage at test jacks provided (TP5-1 and TP6-1, black positive and blue negative) and adjust R63-1 for 12 ± 1 volt. The recorder will perform satisfactorily at any dc filament voltage level within this range.

The output of the 250 volts dc supply may be measured between TP3-1 and TP4-1. This voltage is adjusted by R6-1 and should be set to 250 ± 5 volts.

4.3 Chart Servo Amplifier

The GAIN and TACHOMETER controls of the chart amplifier should be adjusted for maximum servo loop tightness and for critical damping. A measure of loop tightness is the ability of the turntable to return to the same null after being displaced from the null in either direction. Damping is measured by the ability of the turntable to abruptly cease motion. Critical damping is obtained when the turntable stops upon a servo command without noticeable overshoot or undershoot of the null point.

To permit adjustment of the chart system GAIN and TACHOMETER controls, connect the chart system to suitable synchro generators. Turn both the GAIN and TACHOMETER controls fully counterclockwise, then turn the TACHOMETER control approximately 1/4 turn clockwise. Advance the GAIN control clockwise until the chart system is

nulled. Observe the alignment of the pen with one of the angle lines on the chart. The GAIN control should now be set to provide the minimum value of gain which causes the pen to return to the reference line after the chart is forcibly displaced either side of the null. Displacement of the chart from null can be accomplished by manually rotating the turntable in either direction with the fingers.

The TACHOMETER control may now be set for critical damping. A step function should be applied to the chart drive system by operating the CHART MOTION switch. When applying this step function, observe turntable overshoot or undershoot as the turntable approaches the null. The TACHOMETER should be adjusted such that the turntable approaches the null point at a steady rate of speed and stops without overshooting or undershooting. Undershoot is indicated by a noticeable reduction of turntable speed as the null position is approached.

4.4 Pen Servo Amplifier

Three pen servo amplifier adjustments are provided which determine the response of the recording pen when either a logarithmic or square-root pen function is used; these are the GAIN, TACHOMETER, and DAMPING CORRECTION controls. When only a linear pen function is provided, the DAMPING CORRECTION is not used.

When a pattern recorder has more than one pen function, it is necessary to adjust the pen servo amplifier controls for a particular response to provide proper adjustment for all pen responses. For the several models of the pattern recorder, the servo amplifier adjustments for each model should be made with the recorder set to the pen function indicated by the following table:

TABLE I

Pen Function for Servo Amplifier Adjustment

Recorder Model	Pen Function	Perform Adjustments Using Pen Function Below:
APR 31	Linear	Linear
APR 32	Logarithmic	Logarithmic
APR 33	Linear - Logarithmic	Logarithmic
APR 34	Linear - Square Root	Square Root
APR 35	Linear - Log. - Sq. Root	Logarithmic

The procedure for pen servo amplifier adjustment follows:

a. Determine the proper pen function from TABLE I and connect recorder accordingly.

b. Turn the pen servo amplifier GAIN and TACHOMETER controls fully counterclockwise. Set TACHOMETER 1/4 turn clockwise.

c. If recorder response is non-linear (logarithmic or square-root), turn the DAMPING CORRECTION control located on the pen function amplifier fully counterclockwise.

d. Set ATTENUATOR on preamplifier to 20 and apply signal to INPUT.

e. Turn pen servo amplifier GAIN control clockwise until pen nulls. Set signal level for approximately 1/2 scale pen deflection. NOISE COMPRESSION switch must be OFF.

f. Deflect the pen to either side of null with finger to observe servo loop tightness. Set pen servo amplifier GAIN control to minimum value of gain required for the pen to return to an accurate null.

g. Switch ATTENUATOR on preamplifier between 20 db and 30 db positions to introduce pen steps. Set the TACHOMETER control to allow a pen overshoot of approximately 1/8 inch for a down-scale pen step. For logarithmic and square-root pen functions, the overshoot will be higher on the upscale pen step.

h. If the pen function is logarithmic or square-root, turn the DAMPING CORRECTION control located on the pen function ampli-

fier to equalize the overshoot on the upscale and downscale pen steps. If the pen function is linear disregard this step.

i. Readjust the TACHOMETER control for minimum pen overshoot and undershoot of the null point.

V. SERVICE AND MAINTENANCE INSTRUCTIONS

5.1 General Procedures

In the event of faulty operation of any part of the pattern recorder, a visual inspection of tubes, cable connections, and other components should be completed first. Afterward, standard maintenance procedures should be followed to isolate the trouble to a particular stage and then to the defective component. To aid in the maintenance, the circuit diagram provides typical plate voltage and current values, component values, and parts numbers. In addition, voltage and gain tables are furnished to serve as a guide for testing the static and dynamic circuit operation. Similar tables for the preamplifiers and pen function amplifer are furnished in separate instruction manuals.

5.2 Static Measurements

The following table provides typical values of voltages present at the tube pins of the amplifier stages. These voltages are measured with respect to ground (TP4-1) using a 20,000 ohm-per-volt dc voltmeter and a 1,000 ohm-per-volt ac voltmeter. These voltages are subject to standard tolerances of ± 10%. During measurement, both the recording pen system and the chart system should be nulled.

TABLE II DC and RMS AC Voltages

Tube or Transistor Number	Tube or Transistor Pins								
	Base 1	Emitter 2	Collector 3	4	5	6	7	8	9
V1-1	65	0	1.8	6.3 ac	6.3 ac	100	0	1.6	0
V2-1	81	0	0.8	6.3 ac	6.3 ac	157	81	86	0
V3-1	6.3 ac	265	285	--	--	0	17	0	--
V4-1	6.3 ac	265	285	--	--	0	17	0	--
V5-1	62	--	6.3 ac	0	62	0	1.8	--	--
V6-1	208	0	13.2	6.3 ac	6.3 ac	213	0	13.2	0
V7-1	6.3 ac	265	285	--	--	0	17	0	--
V8-1	6.3 ac	265	285	--	--	0	17	0	--
V9-1	--	305	--	300 ac	--	300 ac	--	305	--
V10-1	--	410	--	345 ac	--	345 ac	--	410	--
V11-1	400	247	250	--	--	250	247	3	400
V12-1	247	85	86	6.3 ac	6.3 ac	250	85	86	0
V13-1	150	0	--	0	150	--	0	--	--
V14-1	85	33	35	6.3 ac	6.3 ac	250	32	35	0
Q1-1	-12.6	-12.3	-17.7	--	--	--	--	--	--

5.3 Dynamic Measurements

The following table provides typical values of voltage-gain-per-stage for the amplifiers located on the amplifier and power supply chassis. A signal may be applied to either the pen servo amplifier or the chart servo amplifier to permit gain measurement by manually displacing the recording pen or the chart roll from a null with the servo motors off. Only a slight displacement from null should be introduced to prevent amplifier saturation. NOISE COMPRESSION should be OFF and pen servo amplifier GAIN control set fully clockwise.

TABLE III 60 cps Gain

Gain Measured		Voltage Gain
From	To	
Pin 2, V1-1	Pin 1, V1-1	14
Pin 1, V1-1	Pin 6, V1-1	27
Pin 6, V1-1	Pin 1, V2-1	4
Pin 1, V2-1	Pin 6, V2-1	0.9
Pin 6, V2-1	Pin 2, V3-1	23
Pin 8, V2-1	Pin 2, V4-1	23
Pin 6, V2-1	Pin C to D, J1-1	11
Pin 6, V5-1	Pin 1, V5-1	14
Pin 1, V5-1	Pin 1, V6-1	1.5
Pin 1, V5-1	Pin 1, V6-1	2.2
Pin 6, V6-1	Pin 2, V7-1	22
Pin 1, V6-1	Pin 2, V8-1	22
Pin 6, V6-1	Pin G to H, J3-1	11

The peak-to-peak ripple present at the output of each of the three dc power supplies is shown by Table IV. To maintain a minimum of hum in the pen amplifier signal channel, these hum levels should be less than the values shown with full load on the power supplies and servo loops nulled.

TABLE IV Power Supply Ripple

Power Supply Voltage (dc)	Peak-to-Peak Ripple
12	0.5 volts
250	10 millivolts
285	3 volts

5.4 Plug-in Potentiometer Phasing

The plug-in potentiometers are factory adjusted for proper alignment with the pattern recorder when properly installed in place. In the event a plug-in potentiometer is disassembled, the following alignment procedure should be followed to assure proper operation;

a. Remove cover from pen drive assembly and rotate drive gear (G, Figure 9) fully clockwise against stop.

b. With the potentiometer drive gear against the stop, the recording pen should be positioned approximately 1/16 inch below lower end of chart scale. If this is not the case, loosen the pen cable clamp (Y, Figure 9) and properly position the pen on the cable; then tighten screws.

c. With the plug-in potentiometer in place in the recorder, position the recording pen to the stop position at the left of the chart scale. The proper potentiometer element phasing may be determined by resistance measurements made with the pattern recorder OFF and with P3-2 (potentiometer cable connector) disconnected from the pen function amplifier. These resistance measurements are made between the pins of P3-2 as shown by the following table:

TABLE V Potentiometer Phasing Data

Plug-in Potentiometer Model Number	Potentiometer Function	Potentiometer Element Location	Measure Between P3-2 Pins:	Phase Potentiometer for Resistance of:
P-1	Linear	---	A to F	100 ± 25 ohms
P-2	Linear Square-root	Upper Lower	A to F C to D	100 ± 25 ohms 5 to 10 ohms
P-3	Logarithmic (40 db)	---	D to E	175 ± 25 ohms
P-3-2	Logarithmic (20 db)	---	D to E	100 ± 25 ohms
P-4	Logarithmic (60 db)	---	D to E	175 ± 25 ohms

The preceding resistance measurements must be made with the potentiometer drive gear fully clockwise against the stop (pen set 1/16 inch below chart scale). To phase a potentiometer element, the outer case must first be removed; then the potentiometer element lock ring loosened to permit rotation. When the plug-in potentiometer unit consists of two potentiometer elements ganged together, the upper unit must be phased first and locked before phasing of the lower unit is attemped.

It is possible in some cases to set the potentiometer element for the proper resistance value but on the wrong side of the break or null (zero resistance). After a potentiometer element is phased and locked to provide the proper resistance measurements, the pen should be slowly moved upscale while observing the resistance change. For all potentiometer elements, this resistance should continually increase indicating that the break or null does not occur within the limits of pen motion.

In the case of a square-root potentiometer element, best response is obtained with the break occurring as close to the lower scale pen stop position as possible.

After phasing a logarithmic potentiometer element, an additional check should be made. Measure the resistance between pins E and F of P3-2 and set the recording pen upscale against the stop. Moving the pen downscale from the stop should provide an increasing value of resistance. If a jump or discontinuity occurs, the potentiometer element should be positioned to move

the discontinuity just outside the upper scale limit of the pen excursion.

5.5 Mechanical Components

All anti-friction bearings used in the assembly of the Series APR 30 Polar Recorder Head are precision bearings (ABEC-1 or better) and are furnished with seals and permanent lubrication. These bearings should require no maintenance or lubrication during the normal life of the recorder. The only part requiring frequent lubrication is the pen slide bar (C, Figure 9). One or two drops of light machine oil should be applied to this bar at least once a week to minimize wearing of the pen holder bearings.

Other points which should be lubricated with a light film of light machine oil at least once every three months are as follow:

a. (H, Figure 9) Potentiometer Gear
b. (I, Figure 9) Precision Idler Gear
c. (R, Figure 9) Gear Clamp
d. (D, Figure 9) Each end of eccentric pen lift bar.

SYNCHRO ELECTRICAL ZERO

The electrical zero of a synchro is defined as that position of the rotor with respect to the stator at which a minimum fundamental voltage is induced in the secondary circuit, and where this secondary voltage is in phase with the primary voltage.

There are two null positions for any synchro. The correct null can be found by connecting the synchro to a voltage source and voltmeter as shown in Figure 1, then determining coarse zero by turning the rotor.* As the rotor is turned, one null point near the correct electrical zero will be found. To determine the fine electrical zero, connect the synchro as shown in Figure 2 and adjust the rotor slightly until a null is established. This is the exact electrical zero.

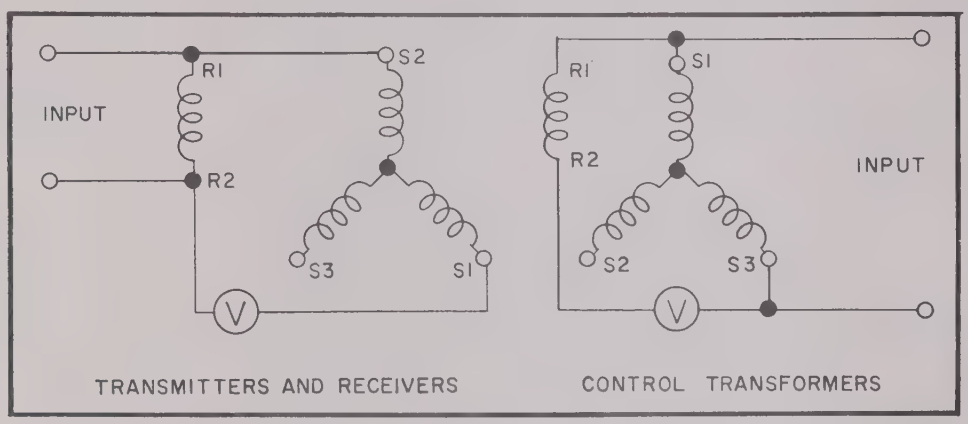

FIGURE 1
COARSE ZERO

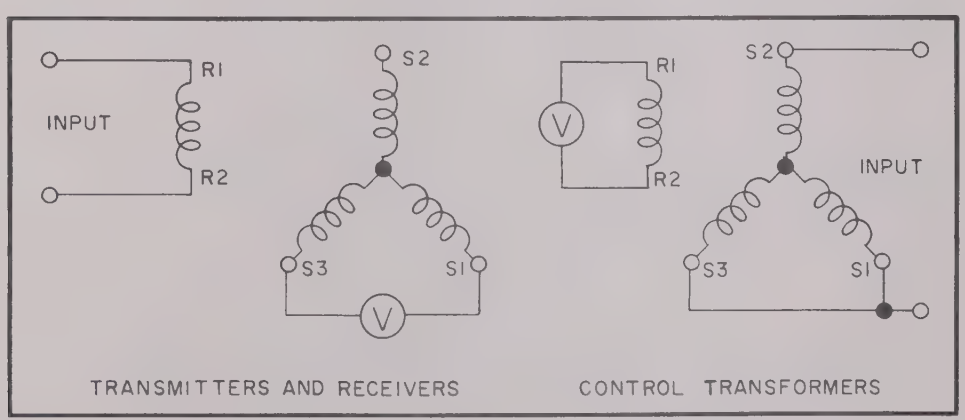

FIGURE 2
FINE ZERO

*Effective rotor rotation can be achieved by loosening the synchro mounting clamps and turning the synchro housing.

PARTS LIST

POLAR PATTERN RECORDER

MANUFACTURERS' CODE LETTERS

Code	Manufacturer
A	Aerovox Corporation
AE	Amphenol Electronics Corporation
AP	Airpax Products Company
AX	Amperex-Electronics Corporation
BAR	Barber-Colman Company
BUS	Bussman Manufacturing Division - McGraw-Edison Co.
C	Chicago Standard
CD	Cornell-Dubilier Electric Corporation
CH	Cutler-Hammer, Incorporated
CRL	Centralab Division of Globe Union, Incorporated
DM	Diehl Manufacturing Company
DPD	Delco Products Division - General Motors Corporation
G	Grayhill, Incorporated
GC	General Cement Manufacturing Company
GE	General Electric Company
HH	Hubbell, Harvey, Incorporated
L	Littelfuse, Incorporated
MS	Micro Switch Division - Minneapolis Honeywell
O	Ohmite Manufacturing Company
OE	Osborn Electric
PB	Potter & Brumfield, Incorporated
PMC	Phillips Control Corporation
PY	Pyramid Electronic Corporation
SA	Scientific-Atlanta, Incorporated
ST	Sarkes Tarzian, Incorporated
SY	Sylvania
T	Triad Transformer Corporation
TE	Transitron Electronic Corporation

MANUFACTURERS CODE LETTERS - continued

Code	Manufacturer
TO	Tru-Ohm Products Division Monel Engineering & Manufacturing, Incorporated
USC	U. S. Semcor
VER	Vernitron Corporation

PARTS LIST

SERIES APR 20/30

AMPLIFIER AND POWER SUPPLY

Component Designation	Description	Mfr.*	Mfr. Part No.
C1-1	Capacitor: fixed, paper 0.01 µfd, 400 V DCW	CD	WMF 451E
C3-1 C4-1 C5-1	Capacitor: fixed, tubular 0.047 µfd, 400 V DCW	CD	WMF 4547E
C6-1	Capacitor: fixed, paper 0.01 µfd, 400 V DCW	CD	WMF 451E
C7-1 C8-1	Capacitor: fixed, tubular 0.047 µfd, 400 V DCW	CD	WMF 4547E
C9A/B-1	Capacitor: fixed, electrolytic 10-10 µfd, 450 V DCW	A	AFH 2-47
C10-1	Capacitor: fixed, bathtub, paper 2 x 0.2 µfd, 600 V DCW	PY	2PDMR 6-P2
C11-1	Capacitor: fixed, electrolytic 25 µfd, 25 V DCW	A	PWE 25025
C12A/B-1	Capacitor: fixed, electrolytic 10-10 µfd, 450 V DCW	A	AFH 2-47
C13-1	Capacitor: fixed, paper 0.001 µfd, 400 V DCW	A	P488N
C14-1	Capacitor: fixed, paper 0.01 µfd, 400 V DCW	A	P488N
C15-1 C16-1	Capacitor: fixed, paper 0.05 µfd, 400 V DCW	A	P488N
C17-1	Capacitor: fixed, electrolytic 25 µfd, 25 V DCW	A	PWE 25025
C18-1	Capacitor: fixed, bathtub, paper 0.25 µfd, 600 V DCW	A	JP630M
C19A/B-1 C20A/B-1	Capacitor: fixed, electrolytic 10-10 µfd, 500 V DCW	A	AFH 2-67
C21-1	Capacitor: fixed, paper 0.1 µfd, 400 V DCW	A	P488N

*See "TABLE OF MANUFACTURERS' CODE LETTERS"

PARTS LIST - continued

AMPLIFIER AND POWER SUPPLY

Component Designation	Description	Mfr.*	Mfr. Part No.
C22-1	Capacitor: fixed, paper 0.01 μfd, 400 V DCW	A	P488N
C23-1	Capacitor: fixed, electrolytic 1000 μfd, 25 V DCW	A	AFH1-10
C24-1 C25-1	Capacitor: fixed, electrolytic 500 μfd, 25 V DCW	A	AFH 1-08
CR1-1	Diode: silicon	TE	SV 804
CR2-1	Diode: crystal	TE	1N277
CR3-1	Diode: silicon	TE	SV 804
CR4-1	Diode: crystal	TE	1N277
CR5-1 CR6-1	Diode: silicon	TE	S4G
CR7-1	Rectifier: selenium bridge	ST	604B
CR8-1	Diode	USC	1N1354A
DS1-1	Bulb: incandescent, 6.3V, bayonet	GE	47
F1-1 F2-1	Fuse: type 3AG, 1.5 amperes Fuse Holder: panel mounting	L BUS	31201.5 HKP
F3-1	Fuse: type 3AG, 3 amperes Fuse Holder: panel mounting	L BUS	312003 HKP
F4-1	Fuse: type 3AG, 1.5 amperes Fuse Holder: panel mounting	L BUS	31201.5 HKP
J1-1	Connector	AE	97-3102A-14S-2S
J2-1	Connector: AC	HH	7255
J3-1	Connector	AE	97-3102A-18-8S
J4-1	Connector	AE	97-3102A-18-19S
J5-1	Connector	AE	97-3102A-18-1S
J9-1	Connector: miniature	AE	165-14
J10-1	Connector: miniature	AE	165-10
K1-1	Chopper: AC-DC, SPDT	AP	175
L1-1	Choke: filter	C	RH 12200
L2-1	Choke: filter	C	RH 1585
P6-1	Connector: AC, power	HH	7486
P7-1	Connector	AE	97-3106A-18-19P
P8-1	Connector	AE	97-3106A-18-1P
Q1-1	Transistor: power, type PNP	DPD	2N441
R1-1 R2-1	Resistor: fixed, composition 10 k ohms, 10%, 1/2 watt	O	"Little Devil"

*See "TABLE OF MANUFACTURERS' CODE LETTERS"

PARTS LIST, Continued

AMPLIFIER AND POWER SUPPLY

Component Designation	Description	Mfr.*	Mfr. Part No.
R3-1	Resistor: fixed, composition 10 ohms, 10%, 1/2 watt	O	"Little Devil"
R4-1	Resistor: fixed, composition 33 k ohms, 10%, 1/2 watt	O	"Little Devil"
R5-1	Resistor: fixed, composition 10 k ohms, 10%, 1/2 watt	O	"Little Devil"
R6-1 R7-1	Resistor: fixed, composition 1 m ohm, 10%, 1/2 watt	O	"Little Devil"
R8-1	Resistor: fixed, composition 470 k ohms, 10%, 1/2 watt	O	"Little Devil"
R9-1	Resistor: fixed, composition 1 k ohm, 10%, 1/2 watt	O	"Little Devil"
R10-1	Resistor: fixed, composition 100 k ohms, 10%, 1/2 watt	O	"Little Devil"
R11-1	Resistor: fixed, composition 270 k ohms, 10%, 1/2 watt	O	"Little Devil"
R12-1	Resistor: fixed, composition 4.7 m ohms, 10%, 1/2 watt	O	"Little Devil"
R13-1	Resistor: fixed, composition 270 k ohms, 10%, 1/2 watt	O	"Little Devil"
R14-1 R15-1	Resistor: fixed, composition 470 k ohms, 10%, 1/2 watt	O	"Little Devil"
R16-1	Resistor: fixed, composition 33 k ohms, 10%, 1/2 watt	O	"Little Devil"
R17-1	Resistor: variable, composition 250 k ohms, 2 watts	O	CLU-2541
R18-1	Resistor: fixed, composition 470 k ohms, 10%, 1/2 watt	O	"Little Devil"
R19-1	Resistor: fixed, composition 4.7 k ohms, 10%, 1/2 watt	O	"Little Devil"
R20-1	Resistor: fixed, composition 1 m ohm, 10%, 1/2 watt	O	"Little Devil"
R21-1 R22-1	Resistor: fixed, composition 82 k ohms, 10%, 1/2 watt	O	"Little Devil"

*See "TABLE OF MANUFACTURERS' CODE LETTERS"

PARTS LIST, Continued

AMPLIFIER AND POWER SUPPLY

Component Designation	Description	Mfr.*	Mfr. Part No.
R23-1 R24-1	Resistor: fixed, composition 470 k ohms, 10%, 1/2 watt	O	"Little Devil"
R25-1	Resistor: fixed, composition 100 k ohms, 10%, 1/2 watt	O	"Little Devil"
R26-1 R27-1	Resistor: fixed, composition 47 k ohms, 10%, 1/2 watt	O	"Little Devil"
R28-1	Resistor: fixed, composition 1 k ohm, 10%, 1 watt	O	"Little Devil"
R29-1	Resistor: fixed, axial lead, ww 200 k ohms, 3 watts	TO	VAL-3
R30-1	Resistor: variable, composition 1 k ohm, 2 watts	O	CLU-1021
R31-1	Resistor: variable, composition 25 k ohms, 2 watts	O	CLU-2531
R32-1	Resistor: fixed, composition 330 k ohms, 10%, 1/2 watt	O	"Little Devil"
R33-1	Resistor: variable, composition 25 k ohms, 2 watts	O	CLU-2531
R34-1	Resistor: fixed, composition 100 k ohms, 10%, 1/2 watt	O	"Little Devil"
R35-1	Resistor: fixed, composition 2.2 k ohms, 10%, 1 watt	O	"Little Devil"
R36-1	Resistor: fixed, composition 100 k ohms, 10%, 1/2 watt	O	"Little Devil"
R37-1	Resistor: fixed, composition 1 k ohm, 10%, 1/2 watt	O	"Little Devil"
R38-1	Resistor: fixed, composition 47 k ohms, 10%, 1/2 watt	O	"Little Devil"
R39-1	Resistor: fixed, composition 15 k ohms, 10%, 1/2 watt	O	"Little Devil"
R40-1	Resistor: fixed, composition 47 k ohms, 10%, 1/2 watt	O	"Little Devil"
R41-1	Resistor: fixed, composition 100 k ohms, 10%, 1/2 watt	O	"Little Devil"
R42-1 R43-1	Resistor: fixed, composition 470 k ohms, 10%, 1/2 watt	O	"Little Devil"

*See "TABLE OF MANUFACTURERS' CODE LETTERS"

PARTS LIST, Continued

AMPLIFIER AND POWER SUPPLY

Component Designation	Description	Mfr.*	Mfr. Part No.
R44-1	Resistor: fixed, composition 100 ohms, 10%, 1/2 watt	O	"Little Devil"
R45-1	Resistor: fixed, ww 200 ohms, 5 watts	TO	FRL-5
R46-1	Resistor: fixed, composition 100 k ohms, 10%, 1 watt	O	"Little Devil"
R47-1	Resistor: fixed, composition 1 m ohm, 10%, 1/2 watt	O	"Little Devil"
R48-1 R49-1	Resistor: fixed, composition 47 ohms, 10%, 1/2 watt	O	"Little Devil"
R50-1	Resistor: fixed, composition 68 k ohms, 10%, 1/2 watt	O	"Little Devil"
R51-1	Resistor: fixed, composition 100 k ohms, 10%, 1/2 watt	O	"Little Devil"
R52-1	Resistor: fixed, composition 82 k ohms, 10%, 1/2 watt	O	"Little Devil"
R53-1	Resistor: fixed, axial lead, ww 3 k ohms, 10 watts	TO	VAL-10
R54-1	Resistor: fixed, composition 180 k ohms, 10%, 1/2 watt	O	"Little Devil"
R55-1	Resistor: fixed, composition 47 k ohms, 10%, 1/2 watt	O	"Little Devil"
R56-1	Resistor: fixed, composition 560 ohms, 10%, 1/2 watt	O	"Little Devil"
R57-1	Resistor: fixed, composition 68 k ohms, 10%, 1/2 watt	O	"Little Devil"
R58-1	Resistor: fixed, composition 100 k ohms, 10%, 2 watts	O	"Little Devil"
R59-1	Resistor: fixed, composition 27 k ohms, 10%, 1/2 watt	O	"Little Devil"
R60-1	Resistor: fixed, composition 270 k ohms, 10%, 1/2 watt	O	"Little Devil"
R61-1	Resistor: variable, composition 50 k ohms, 2 watts	O	CLU-5031
R62-1	Resistor: fixed, ww 1 ohm, 5 watts	TO	FRL-5

*See "TABLE OF MANUFACTURERS' CODE LETTERS"

PARTS LIST, Continued

AMPLIFIER AND POWER SUPPLY

Component Designation	Description	Mfr.*	Mfr. Part No.
R63-1	Resistor: variable, composition 250 ohms, 2 watts	O	CLU-5001
R64-1	Resistor: fixed, composition 1 k ohm, 2 watts	TO	"Little Devil"
R65-1 R66-1	Resistor: fixed, composition 47k ohms, 10%, 1/2 watt	O	"Little Devil"
RT1-1	Bulb: incandescent, 6.3 V bayonet base	GE	1816
S1-1	Switch: toggle, SPDT	CH	7590-K6
S2-1	Switch: toggle, SPST	CH	7501-K13
T1-1	Transformer: interstage	T	JO-11
T2-1 T3-1	Transformer: output	T	S24A
T4-1	Transformer: power	OE	8561
T5-1	Transformer: power	OE	8560
V1-1	Tube: electron, type 12AT7	GE	12AT7
V2-1	Tube: electron, type 12AX7	GE	12AX7
V3-1 V4-1	Tube: electron, type 7C5	SY	7C5
V5-1	Tube: electron, type 6C4	GE	6C4
V6-1	Tube: electron, type 12AU7	GE	12AU7
V7-1 V8-1	Tube: electron, type 7C5	GE	7C5
V9-1	Tube: electron, type 5U4GT	GE	5U4GT
V10-1	Tube: electron, type 5AR4	AX	5AR4
V11-1	Tube: electron, type 6BX7	GE	6BX7
V12-1	Tube: electron, type 12AX7	GE	12AX7
V13-1	Tube: electron, type OA2	SY	OA2
V14-1	Tube: electron, type 12AX7	GE	12AX7

*See "TABLE OF MANUFACTURERS' CODE LETTERS"

PARTS LIST

SERIES APR 30
POLAR PATTERN RECORDER HEAD

Component Designation	Description	Mfr.*	Mfr. Part No.
B1-5 B2-5	Synchro: control transformer	V	23CT6
C1-5	Capacitor: fixed, paper 2 μf, 200 V DCW	A	P82
C2-5 C3-5	Capacitor: fixed, paper 0.05 μf, 400 V DCW	A	P488N
DS1-5	Lamp: incandescent	GE	TS-44
J1-5	Connector: type AN	AE	AN-3102A- 20-7S
J4-5	Connector: type AN	AE	AN-3102A- 14S-2SY
J5-5 J6-5	Connector: type AN	AE	AN-3102A- 12S-3S
L1-5	Solenoid: 115 v, 60cps	PMC	41-C-115-60
MG1-5 MG2-5	Motor: servo, with ac tachometer	DM	FPE 25L-105-1
P2-5	Connector: type AN	AE	AN-3102A- 18-8P
P3-5	Connector: type AN	AE	AN-3102A- 14-2P
S1-5	Switch: toggle, SPST	GC	1330
S2-5	Switch: rotary, 2 pole, 3 position	CRL	PA-2015
T1-5	Transformer: filament 115 v pri., 12.6 sec. center tapped, 1.5 amps.	T	F-25X

*See "TABLE OF MANUFACTURERS' CODE LETTERS"

PARTS LIST

SERIES CCU

CHART CONTROL UNIT

Component Designation	Description	Mfr.*	Mfr. Part No.
C1-6	Capacitor: fixed, electrolytic 25 μf, 150 V DCW	A	SRE
CR1-6	Diode	IR	3DS1
J2-6 J3-6 J4-6	Connector: type AN	AE	97-3102A-20-7S
M1-6	Meter: 10 milliamperes full scale	SE	1227
P1-6 P5-6	Connector: type AN	AE	97-3102A-20-7P
P6-6	Connector: type AN	AE	97-3102A-14S-2PY
R1-6	Resistor: fixed, composition 3.3 k ohms, 10%, 1/2 watt	O	"Little Devil"
R2-6	Resistor: fixed, composition 33 ohms, 10%, 1/2 watt	O	"Little Devil"
R3-6	Resistor: fixed, composition 100 k ohms, 10%, 1/2 watt	O	"Little Devil"
S1-6 S2-6	Switch: rotary, 5 poles, 3 positions	CRL	PA-2015
S3-6	Switch: toggle, DPDT	CH	7565K5

MECHANICAL PARTS LIST
SERIES APR 30
POLAR RECORDER HEAD

Component Designation	Description	Mfr.*	Mfr. Part No.
A	Capillary Pen	SA	APR-MA-2284
B	Pen Holder	SA	APR-MB-2995
C	Pen Slide Bar	SA	APR-MA-2986
D	Pen Lift Bar	SA	APR-MA-2797
E	Pen Bar Support	SA	APR-MA-2787
F	"O" Ring	VM	72708
G	Potentiometer Gear	SA	APR-MC-2469-4
H	Fibre Pulley	SA	APR-MA-1137
I	Idler Gear	SA	APR-MC-2469-10
J	Gear Motor	PIC	H-31-25
K	Pulley Cable Pin	SA	APR-MA-1143
L	Solenoid Connector Wire	SA	APR-MA-2458
M	Pen Lift Arm	SA	APR-MA-2794
N	Solenoid	PCC	41C11-560AX
O	Solenoid Bracket	SA	APR-MA-1126
P	Pen Lift Spring	SA	APR-MA-1112
Q	Cable Drum Stop	SA	APR-MA-3423
R	Gear Clamp	SA	APR-MA-2779
S	Ink Pen Guide	SA	APR-MA-2791
T	Pen Lift Spacer	SA	APR-MA-2796
U	Pen Lift Bar Collar	SA	APR-MA-2987
Y	Pen Cable Clamp	SA	APR-MA-2786

*See "TABLE OF MANUFACTURERS' CODE LETTERS"

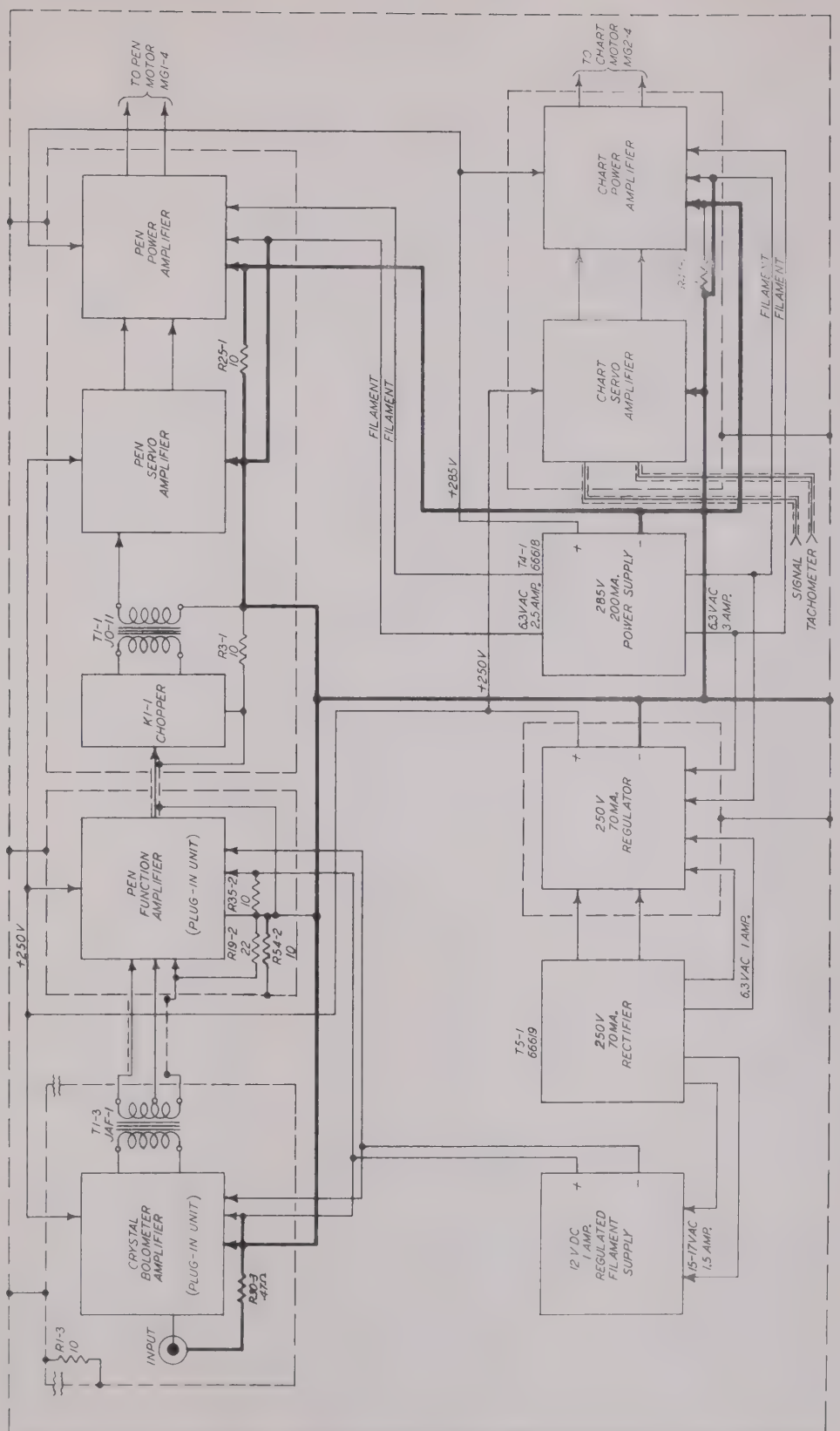

Figure 15. Block Diagram of Recorder Ground Circuit

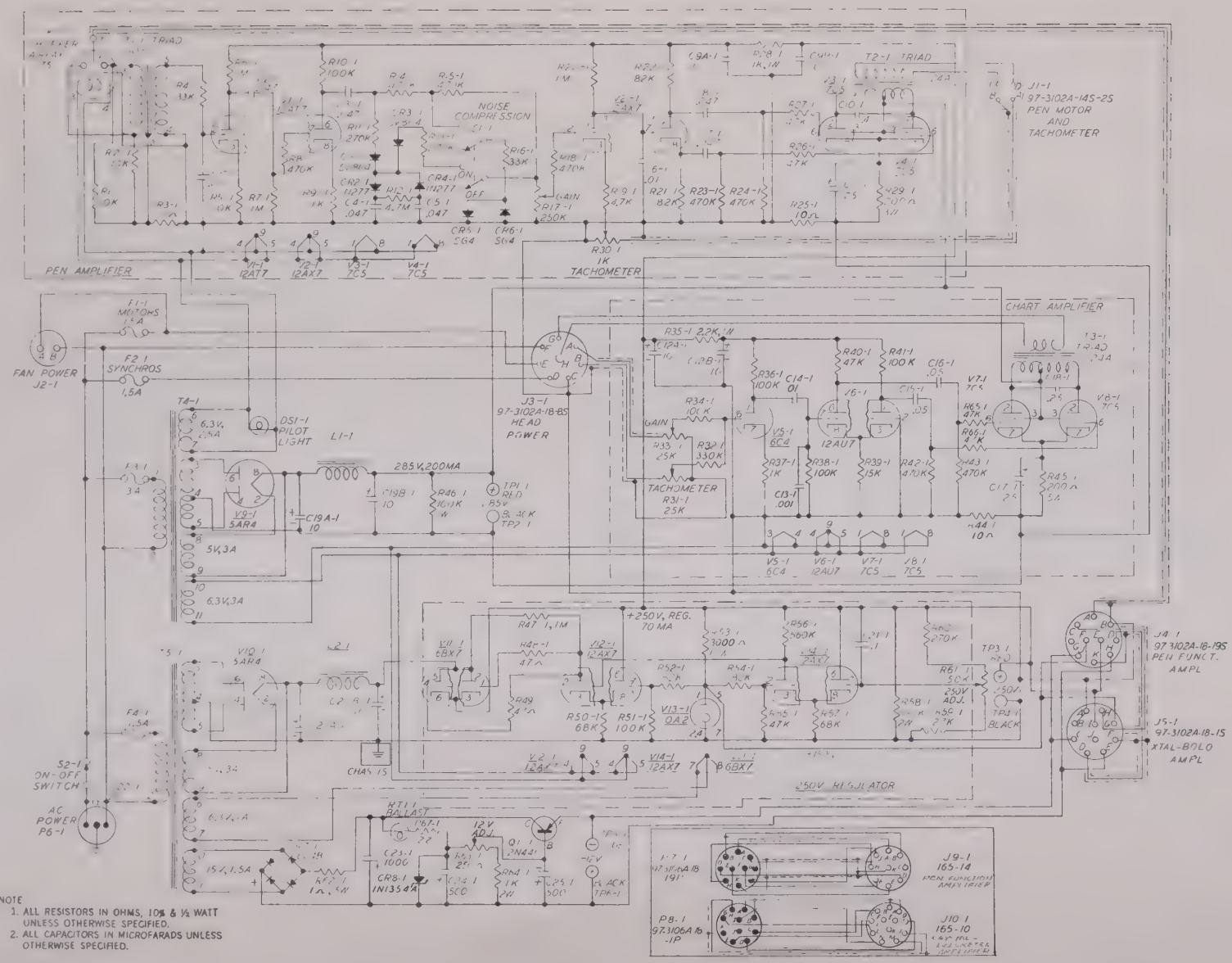

Figure 16. Circuit Diagram of Amplifier and Power Supply Unit.

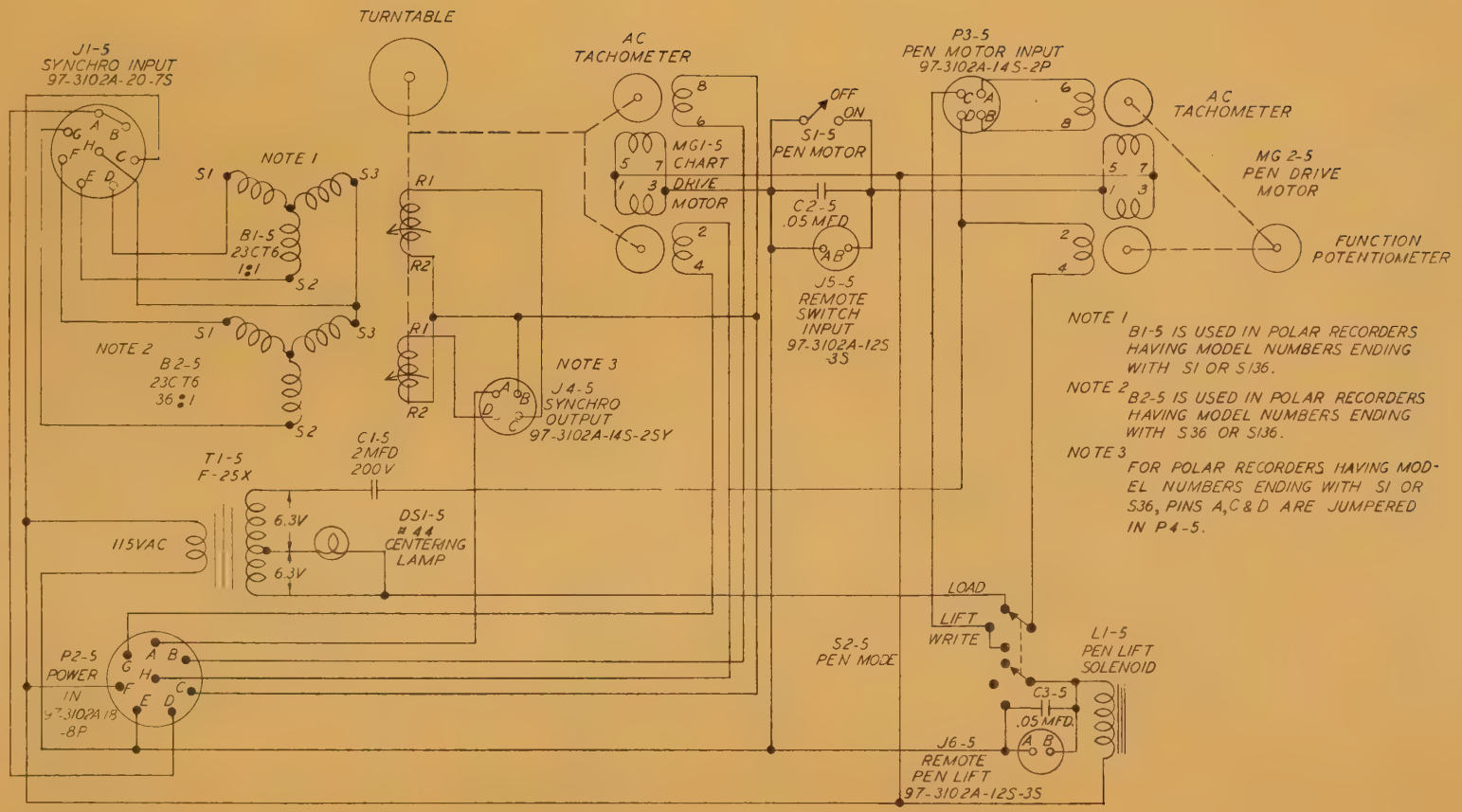

Figure 17. Circuit Diagram, Polar Recorder Head, Series APR 30

Note 1:

A. Only the 1:1 synchro is required for polar recorders having model numbers ending with S1.

B. Only the 36:1 synchro is required for polar recorders having model numbers ending with S36.

C. Both the 1:1 and the 36:1 synchros are required for polar recorders having model numbers ending with S136.

Note 2:

The switching-metering circuit shown enclosed by the dotted line is omitted in polar recorders having model numbers ending with S1 or S36.

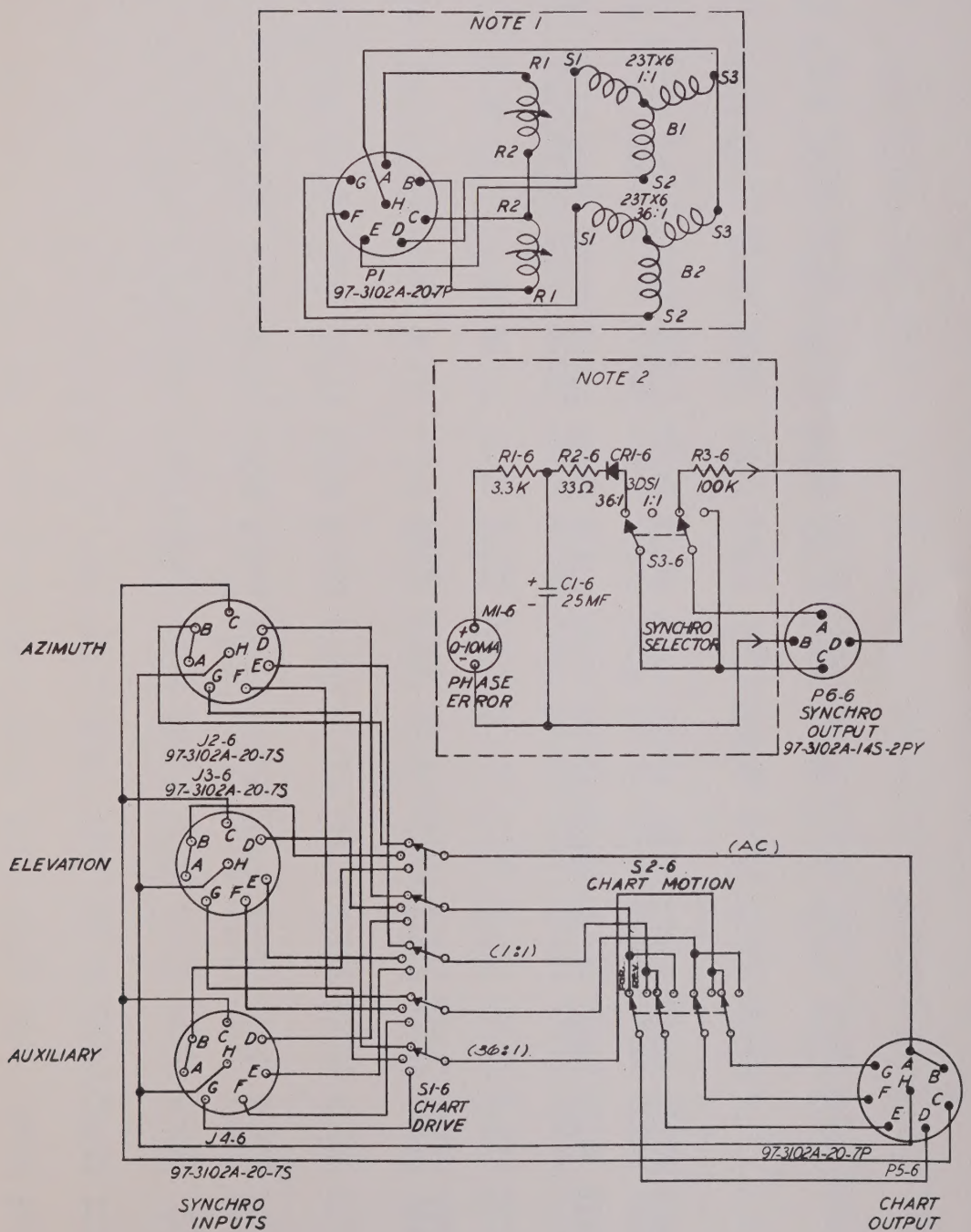

Figure 18. Circuit Diagram of the Series CCU 30 Chart Control Unit.

CONVERSION OF VOLTAGE AND POWER RATIOS TO DECIBELS

The basic chart below indicates the number of decibels (db) corresponding to the listed ratios of voltage or power over the range of −20 to +20 db. For voltage or power ratios greater than those included in the chart, the ratio can be broken down into a product of two numbers, the value in db for each found separately, and the two results added. Example: To convert a power ratio of 2,000:1 to db, express 2,000 as 2×10^3; the number of db corresponding to a power ratio of 2 is very nearly 3, and the number of db for a power ratio of 10^3 is 30. Therefore, the power ratio of 2,000:1 is approximately 30 db + 3 db = 33 db. In the lower right-hand corner of the chart db values for voltage and power ratios of integral powers of 10 are given.

Voltage Ratio	*Power Ratio*	*−db+*	*Voltage Ratio*	*Power Ratio*	*Voltage Ratio*	*Power Ratio*	*−db+*	*Voltage Ratio*	*Power Ratio*	*Voltage Ratio*	*Power Ratio*	*−db+*	*Voltage Ratio*	*Power Ratio*
1.000	**1.000**	**0**	**1.000**	**1.000**	**.447**	**.200**	**7.0**	**2.239**	**5.012**	**.200**	**.0398**	**14.0**	**5.012**	**25.12**
.989	.977	.1	1.012	1.023	.442	.195	7.1	2.265	5.129	.197	.0389	14.1	5.070	25.70
.977	.955	.2	1.023	1.047	.437	.191	7.2	2.291	5.248	.195	.0380	14.2	5.129	26.30
.966	.933	.3	1.035	1.072	.432	.186	7.3	2.317	5.370	.193	.0372	14.3	5.188	26.92
.955	.912	.4	1.047	1.096	.427	.182	7.4	2.344	5.495	.191	.0363	14.4	5.248	27.54
.944	.891	.5	1.059	1.122	.422	.178	7.5	2.371	5.623	.188	.0355	14.5	5.309	28.18
.933	.871	.6	1.072	1.148	.417	.174	7.6	2.399	5.754	.186	.0347	14.6	5.370	28.84
.923	.851	.7	1.084	1.175	.412	.170	7.7	2.427	5.888	.184	.0339	14.7	5.433	29.51
.912	.832	.8	1.096	1.202	.407	.166	7.8	2.455	6.026	.182	.0331	14.8	5.495	30.20
.902	.813	.9	1.109	1.230	.403	.162	7.9	2.483	6.166	.180	.0324	14.9	5.559	30.90
.891	**.794**	**1.0**	**1.122**	**1.259**	**.398**	**.159**	**8.0**	**2.512**	**6.310**	**.178**	**.0316**	**15.0**	**5.623**	**31.62**
.881	.776	1.1	1.135	1.288	.394	.155	8.1	2.541	6.457	.176	.0309	15.1	5.689	32.36
.871	.759	1.2	1.148	1.318	.389	.151	8.2	2.570	6.607	.174	.0302	15.2	5.754	33.11
.861	.741	1.3	1.161	1.349	.385	.148	8.3	2.600	6.761	.172	.0295	15.3	5.821	33.88
.851	.724	1.4	1.175	1.380	.380	.145	8.4	2.630	6.918	.170	.0288	15.4	5.888	34.67
.841	.708	1.5	1.189	1.413	.376	.141	8.5	2.661	7.079	.168	.0282	15.5	5.957	35.48
.832	.692	1.6	1.202	1.445	.372	.138	8,6	2.692	7.244	.166	.0275	15.6	6.026	36.31
.822	.676	1.7	1.216	1.479	.367	.135	8.7	2.723	7.413	.164	.0269	15.7	6.095	37.15
.813	.661	1.8	1.230	1.514	.363	.132	8.8	2.754	7.586	.162	.0263	15.8	6.166	38.02
.804	.646	1.9	1.245	1.549	.359	.129	8.9	2.786	7.762	.160	.0257	15.9	6.237	38.90
.794	**.631**	**2.0**	**1.259**	**1.585**	**.355**	**.126**	**9.0**	**2.818**	**7.943**	**.159**	**.0251**	**16.0**	**6.310**	**39.81**
.785	.617	2.1	1.274	1.622	.351	.123	9.1	2.851	8.128	.157	.0246	16.1	6.383	40.74
.776	.603	2.2	1.288	1.660	.347	.120	9.2	2.884	8.318	.155	.0240	16.2	6.457	41.69
.767	.589	2.3	1.303	1.698	.343	.118	9.3	2.917	8.511	.153	.0234	16.3	6.531	42.66
.759	.575	2.4	1.318	1.738	.339	.115	9.4	2.951	8.710	.151	.0229	16.4	6.607	43.65
.750	.562	2.5	1.334	1.778	.335	.112	9.5	2.985	8.913	.150	.0224	16.5	6.683	44.67
.741	.550	2.6	1.349	1.820	.331	.110	9.6	3.020	9.120	.148	.0219	16.6	6.761	45.71
.733	.537	2.7	1.365	1.862	.327	.107	9.7	3.055	9.333	.146	.0214	16.7	6.839	46.77
.724	.525	2.8	1.380	1.905	.324	.105	9.8	3.090	9.550	.145	.0209	16.8	6.918	47.86
.716	.513	2.9	1.396	1.950	.320	.102	9.9	3.126	9.772	.143	.0204	16.9	6.998	48.98
.708	**.501**	**3.0**	**1.413**	**1.995**	**.316**	**.100**	**10.0**	**3.162**	**10.000**	**.141**	**.0200**	**17.0**	**7.079**	**50.12**
.700	.490	3.1	1.429	2.042	.313	.0977	10.1	3.199	10.23	.140	.0195	17.1	7.161	51.29
.692	.479	3.2	1.445	2.089	.309	.0955	10.2	3.236	10.47	.138	.0191	17.2	7.244	52.48
.684	.468	3.3	1.462	2.138	.306	.0933	10.3	3.273	10.72	.137	.0186	17.3	7.328	53.70
.676	.457	3.4	1.479	2.188	.302	.0912	10.4	3.311	10.96	.135	.0182	17.4	7.413	54.95
.668	.447	3.5	1.496	2.239	.299	.0891	10.5	3.350	11.22	.133	.0178	17.5	7.499	56.23
.661	.437	3.6	1.514	2.291	.295	.0871	10.6	3.388	11.48	.132	.0174	17.6	7.586	57.54
.653	.427	3.7	1.531	2.344	.292	.0851	10.7	3.428	11.75	.130	.0170	17.7	7.674	58.88
.646	.417	3.8	1.549	2.399	.288	.0832	10.8	3.467	12.02	.129	.0166	17.8	7.762	60.26
.638	.407	3.9	1.567	2.455	.285	.0813	10.9	3.508	12.30	.127	.0162	17.9	7.852	61.66
.631	**.398**	**4.0**	**1.585**	**2.512**	**.282**	**.0794**	**11.0**	**3.548**	**12.59**	**.126**	**.0159**	**18.0**	**7.943**	**63.10**
.624	.389	4.1	1.603	2.570	.279	.0776	11.1	3.589	12.88	.125	.0155	18.1	8.035	64.57
.617	.380	4.2	1.622	2.630	.275	.0759	11.2	3.631	13.18	.123	.0151	18.2	8.128	66.07
.610	.372	4.3	1.641	2.692	.272	.0741	11.3	3.673	13.49	.122	.0148	18.3	8.222	67.61
.603	.363	4.4	1.660	2.754	.269	.0724	11.4	3.715	13.80	.120	.0145	18.4	8.318	69.18
.596	.355	4.5	1.679	2.818	.266	.0708	11.5	3.758	14.13	.119	.0141	18.5	8.414	70.79
.589	.347	4.6	1.698	2.884	.263	.0692	11.6	3.802	14.45	.118	.0138	18.6	8.511	72.44
.582	.339	4.7	1.718	2.951	.260	.0676	11.7	3.846	14.79	.116	.0135	18.7	8.610	74.13
.575	.331	4.8	1.738	3.020	.257	.0661	11.8	3.890	15.14	.115	.0132	18.8	8.710	75.86
.569	.324	4.9	1.758	3.090	.254	.0646	11.9	3.936	15.49	.114	.0129	18.9	8.811	77.62
.562	**.316**	**5.0**	**1.778**	**3.162**	**.251**	**.0631**	**12.0**	**3.981**	**15.85**	**.112**	**.0126**	**19.0**	**8.913**	**79.43**
.556	.309	5.1	1.799	3.236	.248	.0617	12.1	4.027	16.22	.111	.0123	19.1	9.016	81.28
.550	.302	5.2	1.820	3.311	.246	.0603	12.2	4.074	16.60	.110	.0120	19.2	9.120	83.18
.543	.295	5.3	1.841	3.388	.243	.0589	12.3	4.121	16.98	.108	.0118	19.3	9.226	85.11
.537	.288	5.4	1.862	3.467	.240	.0575	12.4	4.169	17.38	.107	.0115	19.4	9.333	87.10
.531	.282	5.5	1.884	3.548	.237	.0562	12.5	4.217	17.78	.106	.0112	19.5	9.441	89.13
.525	.275	5.6	1.905	3.631	.234	.0550	12.6	4.266	18.20	.105	.0110	19.6	9.550	91.20
.519	.269	5.7	1.928	3.715	.232	.0537	12.7	4.315	18.62	.104	.0107	19.7	9.661	93.33
.513	.263	5.8	1.950	3.802	.229	.0525	12.8	4.365	19.05	.102	.0105	19.8	9.772	95.50
.507	.257	5.9	1.972	3.890	.227	.0513	12.9	4.416	19.50	.101	.0102	19.9	9.886	97.72
.501	**.251**	**6.0**	**1.995**	**3.981**	**.224**	**.0501**	**13.0**	**4.467**	**19.95**	**.100**	**.0100**	**20.0**	**10.000**	**100.00**
.496	.246	6.1	2.018	4.074	.221	.0490	13.1	4.519	20.42					
.490	.240	6.2	2.042	4.169	.219	.0479	13.2	4.571	20.89	10^{-2}	10^{-3}	30		10^{3}
.484	.234	6.3	2.065	4.266	.216	.0468	13.3	4.624	21.38		10^{-4}	40	10^{2}	10^{4}
.479	.229	6.4	2.089	4.365	.214	.0457	13.4	4.677	21.88		10^{-5}	50		10^{5}
.473	.224	6.5	2.113	4.467	.211	.0447	13.5	4.732	22.39	10^{-3}	10^{-6}	60	10^{3}	10^{6}
.468	.219	6.6	2.138	4.571	.209	.0437	13.6	4.786	22.91		10^{-7}	70		10^{7}
.462	.214	6.7	2.163	4.677	.207	.0427	13.7	4.842	23.44	10^{-4}	10^{-8}	80	10^{4}	10^{8}
.457	.209	6.8	2.188	4.786	.204	.0417	13.8	4.898	23.99		10^{-9}	90		10^{9}
.452	.204	6.9	2.213	4.898	.202	.0407	13.9	4.955	24.55	10^{-5}	10^{-10}	100	10^{5}	10^{10}
											10^{-11}	110		10^{11}
										10^{-6}	10^{-12}	120	10^{6}	10^{12}

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